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ABSTRACT

This report discusses evolution in science education, evaluating the state-by-state treatment of evolution in science standards. It explains the role of evolution as an organizing principle for all the historical sciences. Seven sections include: "Introduction" (the key role of evolution in the sciences); "How Do Good Standards Treat Biological Evolution?" (controversial versus consensual knowledge and why students should learn about evolution); "Extrascientific Issues" (e.g., the diversity of anti-evolutionists, why anti-evolutionism persists, and how science standards reflect creationist pressures); "Evaluation of State Standards" (very good to excellent, good, satisfactory, unsatisfactory, useless or absent, and disgraceful); "Sample Standards"; "Further Analysis" (grades for science standards as a whole); and "Conclusions." Overall, 31 states do at least a satisfactory job of handling the central organizing principle of the historical sciences, 10 states do an excellent or very good job of presenting evolution, and 21 states do a good or satisfactory job. More than one-third of states do not do a satisfactory job. Appended are: two treatment models of evolution: excerpts from California and North Carolina science standards; evolution and its discontents; state documents examined; and ratings of state science standards overall. An annotated bibliography is included. (SM)

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GOOD SCIENCE, BAD SCIENCE:
TEACHING EVOLUTION IN THE STATES

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LAWRENCE S. LERNER

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GOOD SCIENCE, BAD SCIENCE:
TEACHING EVOLUTION IN THE STATES

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THOMAS B. FORDHAM FOUNDATION
OUTSIDE THE BOX

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Foreword

Trouble in Kansas

When two state school board members were unseated in the August (2000) Republican primary election in Kansas, the story made national news. Indeed, the media spotlight had shone on the Kansas race for months. And the school board contest itself was fought harder than such races generally are. One candidate raised over $90,000 and purchased the first TV ad in school board election history.

Why so much attention? Because this election hinged on perhaps the touchiest issue in the school curriculum, one that has drawn headlines at least since the celebrated Scopes trial in 1925: whether and how the public schools will teach evolution. When the votes were counted, the defeated candidates included two of the incumbent board members who a year earlier had voted to erase evolution from the state's academic standards.

It was not just Charles Darwin and biological evolution that vanished in August 1999 (by a 6-4 vote) from the list of topics that young Kansans are expected to master as they pass through the state's public schools. So did the "Big Bang" and all references to the age of the earth itself.

Putting All Fifty States Under the Microscope

All this came as a shock to Americans who assumed that the political debate over teaching evolution in the public schools had itself evolved into generalized acceptance of this central principle of biology. But we were not very surprised. Since 1998, when the Thomas B. Fordham Foundation published its first appraisal of state science standards by Dr. Lawrence Lerner, we have known that a number of states treat evolution in less than competent (and sometimes less than forthright) fashion. When Lerner reviewed state science standards a second time for this Foundation (see *The State of State Standards 2000*), he identified slipshod treatment of biological evolution as a continuing problem in many places. We wanted to know more and felt the public would want to know more.

For example, to what extent is weak handling of evolution simply a manifestation of generally weak science standards and to what extent does it reflect something more complicated? So we asked Lerner (now emeritus professor of physics and astronomy at California State University, Long Beach) to revisit the science standards of the fifty states yet again (using the latest version of these oft-revised documents). This time, the specific focus was on how they treat evolution; the present report is the product of his investigation.

Structure of this Report

The report begins by explaining the role of evolution as an organizing principle for all the historical sciences. Lerner then outlines the components of good science standards that don't shrink from expecting children to learn evolution's central role. He recounts the main arguments that are advanced against the teaching of evolution. (This discussion appears in the report's text, in an appendix, and in an annotated bibliography.) And he characterizes various ways in which states have responded to anti-evolutionist pressures.

The core of his report is a state-by-state evaluation of the treatment of evolution in science standards. The good news is that thirty-one states do an adequate-to-excellent job of this. They do not all have exemplary standards, but they handle evolution pretty much the way they handle the rest of science. (There are a few interesting exceptions, which Lerner discusses.)

The bad news is that nineteen states do a weak-to-reprehensible job of handling evolution in their science standards. Twelve of them shun the word "evolution" and four avoid teaching biological evolution altogether. (Several of the nineteen don't "discriminate" against evolution; they simply have weak science standards across the

board.) Tables in the body of the report show the areas in which various state standards are lacking—and also allow for easy comparison of a state's "evolution grade" with Lerner's evaluation of its overall science standards.

Politicization of Science

Besides reporting this mixed news, can we help to explain what is going on? Part of the explanation is contained in another (April 2000) Foundation report, *Politicizing Science Education*, by Paul Gross, University Professor of Life Sciences emeritus at the University of Virginia. Gross found that evolution is just one of a number of domains where science education is beset—from both left and right—by efforts to bend it to advance the enthusiasms, viewpoints, or doctrines of particular groups. This was disconcerting to learn. While anyone following the K-12 education scene has become accustomed to efforts to manipulate standards and curriculum in other subjects, we might not have expected them in science. But they are there in plenitude—with grave consequences for our children's scientific literacy.

With respect to evolution, Gross was as blunt as one would expect from a distinguished biologist. He dismissed as pure propaganda the claims made by creationists and others trying to discredit the theory of evolution or shield children from learning it. "No evidentiary claim against 'Darwinism' has so far withstood testing," Gross wrote. "On the other hand, the evidence in favor of natural selection grows exponentially and meshes ever more tightly with the rest of science....Any scientist who found a basic flaw or a genuine, deep gap in evolutionary theory would be an overnight celebrity."

Gross's report, particularly the case study of evolution, provoked a strong reaction from some of our readers, including people with whom we ordinarily agree about education issues. As their calls, letters and, especially, e-mails and web postings revealed, the dispute over teaching evolution in U.S. schools is far from over.

Debate over Evolution not so Simple

This dispute, however, turns out to be more complicated, more interesting and more nuanced than many people suppose. Secular liberal intellectuals tend to simplify it into a battle between truth and superstition. People of deep religious faith are more apt to see it as a contest between God and atheism. Political analysts are inclined to depict it as a clash between left and right. In fact, it contains all those elements and more; it is not easily put into a little explanatory box.

As Gross and Lerner both attest, there is no serious debate among today's scientists over whether evolution occurs, though there are disagreements over how it occurs. But even as evolution is accepted as the central concept of biology by almost all scientists, a 1999 Gallup poll found that 68 percent of Americans favor teaching both creationism and evolution in the public schools. In an early-2000 survey by People for the American Way, half the respondents said that evolution is "far from being proven scientifically."

The public, in other words, is not nearly so ready as the scientists to mandate that all schools teach evolution and only evolution. This important political fact begins to explain the dilemma that state policymakers encounter when they set about to promulgate standards for science education.

Role of State Standards

To be sure, state standards do not single-handedly determine what is taught and learned in U.S. schools. Many factors come into play, including the selection of textbooks, the adequacy of teachers' own knowledge, the organization of the curriculum (*e.g.*, how much time is devoted to science), what is included on statewide tests, and whether the tests' results bring consequences for children, teachers, schools, or others. We're also mindful that some states with low marks for academic standards have nonetheless embraced bold and imaginative education reform strategies that appear to be bearing fruit. Standards are obviously not the whole story.

Yet the knowledge and skills set forth in state standards are supposed to form the core of "standards based" education reform. They are meant to serve as the frame to which everything else is attached, the desired outcome that drives countless other decisions about how best to attain it. If a state's standards are unsatisfactory, some of its other reform efforts are apt to be less likely to succeed, maybe even futile. That is why standards matter—and why we have gone to considerable pains to have them carefully evaluated. Academic standards are where a state (or other jurisdiction) spells out what it wants its pupils to come away from school having learned. It may produce good results without having good standards—and fine standards don't assure solid results—but the odds are a lot better if it begins with clear and well-conceived academic expectations.

Standard setting, however, is itself something of a political act. (How political varies with place and circumstance.) The typical state seeks to promulgate standards that represent a reasonable consensus of what experts, practicing educators, and laymen judge to be important for children to know and be able to do. In an area of the curriculum where no such consensus exists within the state, it's exceedingly difficult to establish good standards for students, teachers, and schools.

Science and Faith

As this report makes rather painfully clear, a number of states have not been able to find—or develop—much of a consensus about how and whether evolution should be taught. That's why state standards in this area are such a mixed bag. But the politics of evolution aren't simple. Which is to say, while scientists are more or less unanimous about the science itself, those who oppose teaching evolution and only evolution to schoolchildren are a surprisingly diverse group. As Lerner describes, there are "young earth" creationists who believe that the Earth and its inhabitants arose roughly 6,000 years ago through a process described in the Bible. There are "intelligent design" people who argue that certain complex biological structures and processes could not have arisen through natural selection, and therefore must have been created by some outside force or prior intelligence. There are others—harder to label—who believe simply that what is taught in K-12 science classes goes far beyond what has been proven by scientists and includes uncertain claims on behalf of science that disrespect religious faith. And there are lots of Americans who are okay with evolution being taught so long as religious explanations are also taught—somewhere in the curriculum.

Speaking for ourselves, we believe that schools have an obligation to teach the best science there is. We have certainly not been persuaded by "young earth" advocates or "intelligent design" theorists that K-12 science standards should refrain from providing a full and accurate measure of evolution. Yet we also find much merit in the claims of Americans who believe that schools must respect people's religious and philosophical beliefs, that they should teach about religion and about people's diverse and strongly held beliefs (even if they are precluded from efforts to impart religious faith or observance). They ought not address such matters in science class. But what about history, civics, geography, "contemporary issues," or literature?

The Limits of Science

Scientists, alas, can be as intolerant of religion as creationists are of evolution. Each "side" is too apt to insist that its explanations account for everything, even to shun opportunities for open discourse with people who favor other explanations. Dogma and orthodoxy can be found in science as well as in communities of religious faith.

We don't believe that schools, especially public schools, have any business imparting anybody's dogma. Of course, science classes should teach science, and proper science includes evolution. No equivocation there. People who feel strongly that their children should not be exposed to evolution ought not expect the public schools to assist them with this project. They remain free to consider the options of private or home schooling.

But science teachers also need to respect the reli-

gious faith of their pupils and ought not bridle when parents and clergymen (and other teachers) explain to children that what they're learning in science class is not the whole story. Educating children, after all, entails a lot more than ensuring that they learn science. The school curriculum, too, includes more than science. If it neglects the powerful role of religious faith in human history and contemporary culture, it is not doing a good job of educating its students.

In the concluding section of this report, Dr. Lerner quotes a defense of science education by the primatologist Andrew Petto: "We must help our students master complicated information so that they can appreciate the wonder and grandeur of this view of life..." Scientists and science teachers do well to keep in mind that a large majority of Americans believes that faith in God is the surest way to appreciate the wonder and grandeur of life itself. Schools need to recognize and honor that faith.

By now, we suspect, the reader will at least appreciate that this has been a tough issue for many states, one that a number of them have not handled well. While Kansas has gotten most of the attention, those who set science standards in dozens of other states have faced pressure from groups opposed to the teaching of evolution. We are especially admiring of those state policymakers who, after a fierce battle over evolution, ended up with satisfactory science standards. We wish there were many more of them. We wish, too, that all fifty states would see that their schools respect the elements of a child's education that science alone cannot explain.

About the Author and the Thomas B. Fordham Foundation

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Chester E. Finn, Jr., President
Marci Kanstoroom, Research Director
Thomas B. Fordham Foundation
Washington, DC
September 2000

Executive Summary

Almost all of science is the study of the evolution of systems in time. Biology is no exception; its central organizing principle is the evolution of living things, just as geology centers on the evolution of the earth and astronomy on the evolution of the universe.

That evolution is the central organizing principle of all the historical sciences is not a controversial issue among scientists, nor among most of the world's educated persons. Consequently, the teaching of science worldwide stresses evolution as a routine matter. The United States is exceptional in this regard. In much of this country, the teaching to K-12 students of evolution as scientists see it — particularly biological evolution — evokes bitter controversy. Specifically, many persons object to the teaching of part or all of the facts and theory of evolution in the public schools at the primary and secondary level. This controversy is not really about science but about religion and politics. Those who object to the teaching of evolution often assert that evolution has not taken place, that scientists are profoundly misguided in the picture of the universe that they have developed over the past two centuries, that it is "only fair" to present creationist views to students in tandem with evolution, and that teaching evolution will lead children into immoral lives. In pursuing the first two of these assertions, many of the opponents have advanced what they call "creation science," a pseudoscientific rival to evolution that the courts have repeatedly held to be thinly veiled religion.

This essentially nonscientific controversy is reflected in the primary-secondary (K-12) science standards of many states.[1] It is manifested in a variety of ways, which are discussed in detail in the body of this report. However, there are two principal ways in which objections to the teaching of evolution are expressed:

- The fundamental concepts and facts of evolution are covered to some extent—usually briefly—but the word "evolution" is carefully avoided, at least in the context of biology. Such incorrect and misleading euphemisms as "change over time" are used instead.
- The subject is avoided altogether or barely mentioned, reducing the sciences — especially the biological sciences — to disjointed lists of facts.

There are other ways in which the teaching of evolution is sometimes short-changed. In particular, a few states go much further in dismissing or obscuring important scientific knowledge. These states

are considered on a case-by-case basis in the main text.

The states have been assigned letter grades for their treatment of evolution. The results are displayed in Tables 1 and 2 and Figure 1. (More detailed explanations of the scoring system, as well as a description of what is typically observed in the standards of states receiving particular letter grades, can be found on pages 10-17.)

Table 1. What the Grades Mean

Grade	Score	Number of States*	Description
A	90-100	10	Treatment of evolution is very good or excellent
B	80-89	14	Treatment of evolution is good
C	60-79	7	Treatment of evolution is satisfactory
D	40-59	6	Treatment of evolution is unsatisfactory
F	0-39	12	Treatment of evolution is useless or absent
F-	Negative values	1	Treatment of evolution is disgraceful

*For convenience, we include the District of Columbia in the term "state" throughout this report.

On balance, the news is good. Thirty-one states (almost two-thirds) do at least a satisfactory job of dealing with the central organizing principle of the historical sciences—at least at the level of their statewide academic standards. Ten states do a very good to excellent job (A) of presenting evolution and twenty-one do a good or satisfactory job (fourteen B and seven C).

The bad news, of course, is that more than one-third of all the states do not do a satisfactory job, and thus seriously damage or even erase the possibility of teaching science to their young people as more than a confusing collection of facts. Six states rate an unsatisfactory D and thirteen more an F or worse, signifying that their standards are quite useless for purposes of teaching evolution. These nineteen states are a major focus of this report—and chief sources of the concern that we hope it will raise.

Seven of the nineteen mention evolution, but ten never use the "E-word," one (Maine) uses it exactly once, and one (North Dakota) hides it. Of the seven states that do mention evolution, all but one treat it so skimpily that the coverage is nearly useless. Of the twelve that avoid the term, eight try to sneak in some of evolution's ideas, with results varying from poor to abysmal. Three ignore evolution altogether or touch on it only in a minor way in non-biological contexts. One (Kansas) goes still further, shunning biological evolution while also deleting all references, direct or indirect, to the age of the earth or the universe, including even radioactive decay; for this it has received an "F-".

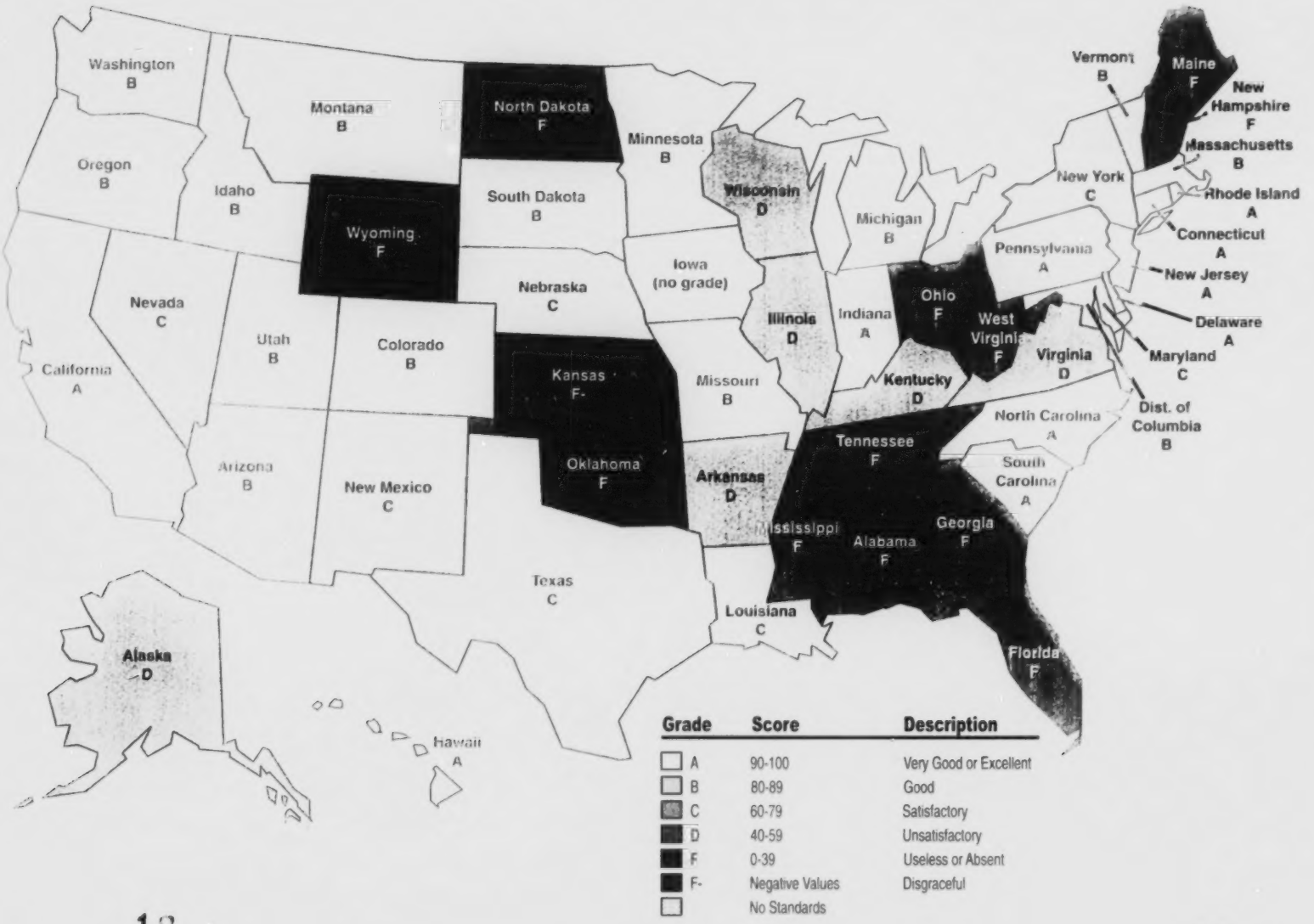

Figure 1. Treatment of Evolution in Science Standards: A State-by-State Evaluation

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Table 2. National Report Card on the Treatment of Evolution in Science Standards

STATE (alphabetical)	SCORE	GRADE
Alabama	9	F
Alaska	48	D
Arizona	82	B
Arkansas	55	D
California	100	A
Colorado	86	B
Connecticut	100	A
Delaware	91	A
District of Columbia	80	B
Florida	16	F
Georgia	7	F
Hawaii	91	A
Idaho	82	B
Illinois	45	D
Indiana	100	A
Kansas	-18	F-
Kentucky	55	D
Louisiana	64	C
Maine	30	F
Maryland	77	C
Massachusetts	82	B
Michigan	84	B
Minnesota	86	B
Mississippi	5	F
Missouri	82	B
Montana	82	B
Nebraska	66	C
Nevada	70	C
New Hampshire	23	F
New Jersey	100	A
New Mexico	73	C
New York	68	C
North Carolina	100	A
North Dakota	9	F
Ohio	28	F
Oklahoma	25	F
Oregon	82	B
Pennsylvania	91	A
Rhode Island	100	A
South Carolina	95	A
South Dakota	82	B
Tennessee	2	F
Texas	64	C
Utah	82	B
Vermont	86	B
Virginia	50	D
Washington	86	B
West Virginia	3	F
Wisconsin	55	D
Wyoming	36	F

STATE (by rank)	SCORE	GRADE
California	100	A
Connecticut	100	A
Indiana	100	A
New Jersey	100	A
North Carolina	100	A
Rhode Island	100	A
South Carolina	95	A
Delaware	91	A
Hawaii	91	A
Pennsylvania	91	A
Colorado	86	B
Minnesota	86	B
Vermont	86	B
Washington	86	B
Michigan	84	B
Arizona	82	B
Idaho	82	B
Massachusetts	82	B
Missouri	82	B
Montana	82	B
Oregon	82	B
South Dakota	82	B
Utah	82	B
District of Columbia	80	B
Maryland	77	C
New Mexico	73	C
Nevada	70	C
New York	68	C
Nebraska	66	C
Louisiana	64	C
Texas	64	C
Arkansas	55	D
Kentucky	55	D
Wisconsin	55	D
Virginia	50	D
Alaska	48	D
Illinois	45	D
Wyoming	36	F
Maine	30	F
Ohio	28	F
Oklahoma	25	F
New Hampshire	23	F
Florida	16	F
Alabama	9	F
North Dakota	9	F
Georgia	7	F
Mississippi	5	F
West Virginia	3	F
Tennessee	2	F
Kansas	-18	F-

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Introduction

In his recent essay, *Politicizing Science Education,*[2] Paul Gross discusses the damage done to science education in the United States by a wide spectrum of pressure groups that, in pursuit of their own political or ideological ends, seek to give K-12 students a distorted view of the methodology and content of science. As Gross shows, many of these efforts have been successful enough to inflict significant damage on science education.

Evolution, the central organizing principle of all the historical sciences, constitutes a prime target for political pressure groups. In many parts of the country, the harm done to the teaching of science by this spectrum of political groups has been considerable. Biological evolution in particular has been a longstanding target. In this report, we concentrate on biological evolution, particularly on how this part of what students are expected to learn about science is set forth in the official state science standards.

Why are standards important? Statewide standards serve as the foundation for a host of curricular activities that affect what goes on in a state's classrooms. District curricula and teachers' lesson plans are often written with the standards in mind. So are the increasingly popular statewide exams administered at certain grade levels, often with such fateful consequences as pupil promotion or graduation hinging on exam scores. Textbook publishers shape the content of their products according to the standards of some of the larger states. Standards are the obvious recourse of parents who want to know what their children are supposed to learn in school and how their classroom activities measure up. And, with an increasingly mobile population, standards provide a basis for some degree of uniformity — at least within states — and thus ease the transition for students who move to new schools. Finally, statewide standards provide a basis for comparative evaluation of what is expected of students in various states, and thus an incentive for change in their K-12 education systems.

We appraised state science standards with respect to their overall quality in two earlier publications: *State Science Standards: An Appraisal of Science Standards in 36 States* (March 1998) and *The State of State Standards 2000* (January 2000), hereinafter referred to as *Standards 2000.*[3] States' grades on the latter study can be found in Table 5 and in Appendix D. Both the earlier studies used the same extensive set of criteria—twenty-five criteria in five categories—to evaluate quality. For each standards document, we considered its: (1) purpose, expectations, and audience, (2) organization, (3) coverage and content, (4) quality, and (5) negative elements that detract from the standards. The detailed criteria may be found in Appendix D.[4]

The treatment of evolution was but one of many matters considered in these earlier, more comprehensive evaluations. It is particularly important, however, as the quality of the treatment of evolution necessarily affects a state's performance vis-à-vis many of the individual criteria under all five general categories. It is thus a matter of special concern to scientists, educators, and policymakers. We therefore resolved to study the treatment of evolution in the standards as a separate matter.

The Key Role of Evolution in the Sciences

What do we mean by *evolution,* and what is its place in the sciences? The universe is a dynamic place at every scale of space and time. Almost all science is the study of the evolution of one system or another — systems as large as the universe itself or as small as a neutrino; systems whose time scales are measured in billions of years or in attoseconds.

Thus, evolution is an indispensable concept across all the sciences. But biological evolution in particular has come to occupy a peculiar position in American education. The public attention that it attracts is different in kind and intensity from that attracted by evolution in other scientific fields. As a consequence of this attention, treatments of the subject in K-12 education vary considerably more in quality and quantity than treatments of any other scientific subject.

This situation is nearly unique to the United States; in no other country is the teaching of bio-

logical evolution subject to similar nonscientific, nonpedagogical pressures.[5]

Although American K-12 science standards are most variable with respect to their treatment of the biological sciences, there is a significant spillover into the other major historical sciences: geology, the evolution of the solar system, and cosmology. The physical sciences are affected as well, but more indirectly.

In the pages that follow, we consider the following questions:

- What constitutes a good set of standards as they concern evolution, biological and otherwise?
- What kinds of public pressures oppose good standards in this area? What are the bases for the opposition?
- How have various states reacted to these pressures?
- What is the effect of such reactions on the quality of science standards overall—and thus, by reasonable inference, on the quality of science education in America today?

How Do Good Standards Treat Biological Evolution?

The writing of science standards is especially challenging on account of the tight and ramified structure of the sciences. It does not suffice to list a collection of facts that students are expected to "know" — more precisely, to memorize. As the French philosopher-scientist Henri Poincaré put it almost a century ago, "Science is constructed of facts as a house is of stones. But science is no more a collection of facts than a house is a heap of stones."

Facts are indispensable, but they would have little meaning were it not for the role of scientific theory. Theory is the logical structure that ties together an otherwise bewildering array of observations, and sieves through the incalculably greater multitude of observations already made to single out those that are significant. Theory also provides the basis for making predictions — for designing the crucial experiments or further observations that make it possible to progress to further knowledge.[6]

In the 1620s, in his *New Atlantis*,[7] Francis Bacon proposed a scientific method that involved little more than accumulating vast bodies of fact and inferring conclusions from them. At just about the same time, his contemporary Galileo Galilei blazed the trail to modern science by forging a methodology whose core was an unremitting interplay of observation and theory construction. So successful was Galileo's methodology, and so universally was it adopted, that a century later Jonathan Swift found it worthwhile to burlesque the Baconian approach in *Gulliver's Travels*. In the nearly three centuries since Swift, we have heaped success upon success by elaborating on Galileo's methodological heritage.

Any decent education in science requires that the student come to understand the central role of theory in scientific methodology. This understanding does not emerge full-blown; young people must grow into the ability to understand the abstractions essential to the methodology at the same time that they accumulate the broad evidentiary basis that cries out for the organizing discipline of ever-broadening theoretical insights. Lacking these insights, the student inevitably comes to see the sciences as a stultifying heap of disconnected facts, some of them counterintuitive and all of them hard to sort out. This luckless student soon learns how to commit the required facts to short-term memory, squeak past the next test, and then thankfully forget what he has so painfully memorized. The present state of scientific literacy among American adults bears dour witness to the ubiquity of this kind of science learning experience.

Controversial vs. Consensual Knowledge

Baconian methodology has its uses in the early stages of a science. As the philosopher of science T. S. Kuhn[8] pointed out, there is much work to be done before a broad theoretical basis for a science can first emerge. In this pre-paradigm stage, workers accumulate vast stores of observations, as did physicists before 1600 or so, chemists before about 1800, geologists before about 1830, biologists before about 1860, geophysicists before about 1950, and psychologists to this day. This work was far from useless, but progress was inhibited by endless controversy as to what observations were most important. In geology, for example, vulcanists vied with neptunists; in psychology, nature still vies with nurture.

With the advent of the first satisfactory theoretical framework, a science experiences a dramatic change. As Kuhn put it, it then becomes unnecessary for each new practitioner in the field to devise his or her own introductory textbook to the subject; there is general consensus as to the basics, and energies can be focused on controversies at the frontiers. As the frontiers advance, the body of noncontroversial, consensual knowledge grows apace. Scientists pursuing such fields are no longer divided into warring schools. This powerful methodological tool underlies the spectacular progress of the sciences over the past four centuries. In physics, this revolution was accomplished mainly by Galileo and Newton; in chem-

istry by Lavoisier and Dalton; in geology by Hutton and Lyell; in biology by Darwin and Wallace; in geophysics by Wegener, Runcorn, and others. (This list is not exhaustive, of course.)

The strong, universally accepted theoretical framework is the basis on which the sciences acquire tighter structure than any other fields of human inquiry except for mathematics. In particular, the sciences are characterized by central organizing principles. For classical physics, these principles are centered on Newton's laws; for modern physics, Newton's laws are extended into and subsumed by the principles of relativity and quantum mechanics. For chemistry, the central principles are conservation of mass and energy, the periodic law and table of the elements, and the laws of quantum mechanics. For geology, the central principle is the theory of plate tectonics and its underlying mechanisms. And for the life sciences, the central principle is biological evolution.

Biological evolution has been the subject of intensive study for about a century and a half. Enormous amounts of data of extraordinarily diverse kinds have been interrelated and made understandable on the basis of the theory. Today, biological evolutionary theory informs, and is vindicated by, a larger and more varied body of evidence than that associated with any of the other major branches of science.[9] Moreover, biological evolution is seamlessly joined with geological evolution, and is completely consistent with the principles of physics and chemistry.

What Students Should Learn About Evolution

Given the central place of evolution in the life sciences, what is required to provide the student with a good understanding of these sciences and the unifying role that evolution plays in them? As with all the sciences, the theoretical framework of evolution is somewhat abstract. Like other theoretical structures, it does not reveal its power to persons who are not familiar with a reasonable sampling of the broad spectrum of facts that the theory explains and correlates. At the primary grade levels, therefore, standards should focus on those basic facts and ideas of evolution that can later be incorporated into broader world views. At the K-3 level, for instance, students should be expected to understand that:

- All living things reproduce.
- Offspring are similar to but not exactly like their parents.
- Offspring have to grow up (or change; *e.g.*, metamorphose) before reproducing themselves.
- There is a fit between individuals, or species, and their environment (*e.g.*, terrestrial, aquatic, aerial).
- The earth is over 4 billion years old, allowing much time for biological as well as geological evolution.

At higher grade levels, these ideas can be supplemented by an understanding of:

- The nature of competition for survival between and within species;
- The consequence that not all offspring live long enough to reproduce;
- The limitation imposed on the number of offspring that survive by such environmental factors as availability of food and water, predators, and temperature;
- The variability among individuals that leads to differential survivability in a particular environment;
- The specialization of species to fit ecological niches and the impact of environmental change on the tenability of those niches;
- The underlying role of genetic variation that results from both sexual reproduction and random mutation;
- The nonrandom way that natural selection operates on the existing population in spite of the many random factors that determine the survival of any individual.

At the middle- and high-school levels, these ideas can be unified, and such concepts as genetic drift, sexual selection, and other significant mechanisms can be introduced. Coevolution and the complex interactions of ecosystems are important applications of the basic concepts. The magnitude of the geological/evolutionary time scale is so different from the time scales of everyday life that it is difficult to grasp, and must be introduced with care. The fact that the same general time scale

underlies both geological and biological evolution is an important link between the two sciences.

In parallel to these macroscopic concepts, the underlying microscopic mechanisms must be introduced at suitable grade levels. These include the relation of genotype to phenotype, DNA as an information carrier, the expression of DNA in protein synthesis and the implications thereof at the various levels of organization from organelles through cells, tissues, organs, and individual organisms, to populations.

It is also important to introduce, at the proper time, the understanding that biological evolution does not take place in a vacuum. The biota of the earth coexist with the nonliving parts of the earth, and each influences the other. Therefore, the facts and, subsequently, the theoretical structure of geological evolution must be introduced in parallel with biological evolution. Similarly, the earth is part of the solar system and the solar system is part of a hierarchy of still larger structures, up to the universe as a whole. The student should be empowered to view the history of the universe, from the general cosmological picture down to the smaller scales characterizing the earth and its smaller elements, as a seamless whole.[19]

There is no single formula for writing good standards that conform to the criteria set forth above. Appendix A gives excerpts from two excellent examples, the standards of California and North Carolina The two are quite different. The California approach is very detailed and introduces sophisticated concepts at relatively early grade levels. The North Carolina approach is more general, describing in principle what is to be taught and following the general statements with specifics less detailed than those in the California standards. Abstractions are introduced mainly in high school. Both sets of standards, however, can function very well as the basis for a thorough science education.

Extrascientific Issues

Evolution (especially biological evolution) remains a controversial issue in American K-12 science education. As we have already noted, this controversy is in no sense scientific. Rather, it is political and, to a degree, religious. Its extrascientific character is highlighted by the fact that, in contrast to the K-12 situation, no controversy at all exists at the university level. Curriculum at the university level is more or less fully under the control of the faculty. As they are experts in their fields, they share the consensus as to basics that is a hallmark of the sciences. In contrast, K-12 instruction is subject to considerable intervention from persons such as school board members and legislators with no expertise in— and often little or no knowledge of — the fields whose curricula they govern. Such persons can and often do consult with experts, but some do not and others flatly reject what experts have to say. Absent an understanding of the compelling logic of the sciences, these persons are liable to be influenced by other pressures.

The Diversity of Anti-Evolutionists

Although the extrascientific pressures against the teaching of biological evolution are diverse, they manifest themselves in three major classes of objections, which correspond to the following factual and theoretical implications of biological evolution:

- To achieve the diversity of life we observe today, the evolutionary process has required several billion years.
- All living things, humans not excepted, are descended from common ancestors.
- The evolutionary process is a natural one susceptible to scientific investigation and thus by definition cannot include supernatural intervention as a necessary component.

The first of these premises conflicts with a particular interpretation of the first few chapters of the Book of Genesis. According to this interpretation, the universe is less than a millionth as old as the scientific evidence implies — that is, a few thousand years rather than some tens of billions. This particular interpretation of Genesis, generally called young-earth creationism, is held mainly by a subset of evangelical Protestants and some ultra-orthodox Jews and Muslims. Young-earth creationists fear that the alternative interpretations of Genesis supported by most Christians and Jews undermine the entire authority of the Bible.

Other religious groups object for the opposite reason. In particular, members of the Nation of Islam (Black Muslims) hold that the universe is trillions of years old, while adherents of some Native American religions hold that their ancestors have been located in their traditional tribal areas forever (*i.e.*, for an infinite time.)

The second premise is objected to by young-earthers and some others who hold that humankind has a special, divinely ordained place in the universe and is the central concern of the divinity. According to this belief, God could not have lumped humans (for whose benefit He created the universe and everything in it) with mere animals, let alone other living things. Such believers hold, moreover, that teaching the biological relationship of humans to other animals inevitably undermines any possible moral or ethical teaching. If, they argue, humans are "only animals" they will "act like animals" (whatever that means).[11] Teaching evolution thus leads to such broadly diverse social phenomena as atheism, communism, socialism, naziism, inflation, homosexuality, women's liberation, sex education, teenage sex, abortion, pornography, family breakdown, school shootings,[12] crime, alcoholism, and drug addiction, to name but a few. The same believers often hold as well the view that certain political and religious positions presuppose adherence to creationism; that is, a person cannot truly be a religious or political conservative without also being a creationist.

The third premise, though shared by the groups discussed above, is the special province of a class of anti-evolutionists called intelligent-design or irreducible-complexity advocates. These persons have revived a position set forth in the seventeenth century by John Ray[13] and just

after 1800 by William Paley.[14] Intelligent-design advocates strongly agree with young-earthers that adherence to an evolutionary view of the biosphere is conducive to atheism, or even that only atheism is consistent with an evolutionary view of the universe, to which they assign the name "naturalism,"[15] a term which they construe as pejorative.[16] Specifically, they dust off Paley's argument and apply it to evolution. They conclude that living beings are too complicated to have evolved, and that their creation by an intelligent (read divine) designer is just the entrée into the natural world that God requires if we are to believe in Him. (See Appendix B for a more detailed discussion of this point.)

Anti-Evolutionism from the Left

Lest it be inferred that anti-evolutionism has roots only in political or religious conservatism, let us note that evolution has had equally vehement opponents on the political left. The classical Marxist view of "Socialist Man" was official doctrine in Stalin's USSR, where it held a position analogous to that of the doctrine of original sin in conservative Christianity. Holding that the evils of society and human immorality stem exclusively from socioeconomic injustices, and that humans will become entirely virtuous in the Marxist utopia, the Stalinist view required rejection of any implications that human behavior might have biological roots. The Lysenkoist debacle was only one of many baleful consequences of this ideology.[17] Utopian socialists, though their approach was more benign than that of Stalin, held similar views of the perfectability of human nature under the proper socioeconomic conditions.[18]

Although Stalinism is dead as a political power, there still exists in America a left-wing intellectual opposition to evolution. (Indeed, some well-known figures whose careers have been marked by a swing from the far left to the far right have maintained throughout a contempt for evolutionary views.) From a practical point of view, the left-wing opposition has far less political power than the opposition at the other end of the spectrum, and we need not consider further its influence on public-school science instruction in the United States.[19] While this left-wing faction has had little effect on American K-12 science teaching, it has done significant damage in other fields, notably environmental education, history, and mathematics.[20] And, although the intelligent-design movement appears to be gaining strength and resources and is sure to be heard from in the future, its views (where they differ from those of the young-earthers) have not yet had disastrous influence on the writing of state science standards.[21]

As can be seen from the brief discussion above, anti-evolution views span a wide spectrum. Moreover, creationist views have evolved over time, responding to judicial and social pressures, competing to fill "ecological" niches, and scouting for new ones to occupy. The literature devoted to anti-evolution views is diverse and vast, and there is likewise a great body of literature that refutes the various species of anti-evolution views. The Bibliography cites some of the best known of the works devoted to these matters. It would be impossible to summarize all this material in brief, but Appendix B attempts to set forth enough to hint at the flavor of the discourse.

Why Anti-Evolutionism Persists

Not surprisingly, the states that find it necessary to wrestle with the teaching of evolution are largely (though not exclusively) those having substantial populations of Protestant evangelicals. Although most Protestant evangelicals probably are not anti-evolutionists, those who are certainly constitute the largest and most significant bloc that opposes the teaching of evolution in public schools. In all probability, the success of creationist efforts at the state level is due to a sympathetic chord struck by creationist activists in a wider public who do not share, or lack strong interest in, creationist ideologies. As Levitt has put it,

> The universal acceptance of heliocentric astronomy is often cited as the classic instance of the triumph of sustained rationality over embedded tradition. ... Most individuals in industrial cultures accept the idea because it has been incessantly repeated since childhood and because there is no apparent emotional cost to accepting it. ... On the other hand, the theory of biological evolution, espe-

cially as regards human origins, still provokes pain, rage, and defiance in many quarters. This is true despite the fact that, in any scientific sense, evolution is as thoroughly established as the picture of the solar system due to Copernicus, Galileo, Kepler, and Newton. Both are equally familiar to the public at large and are vouched for by the same scientific authority. ... It is clear that evolution remains "controversial" at the level of mass opinion, not merely because certain impassioned cultists denounce it, but also because, unlike heliocentric astronomy, it provokes anxieties about the status of humanity in the natural world. ... Its religious opponents thrive, in this culture, precisely because they are able to play on this discomfort ... of many who are, in other aspects, indifferent to the underlying theology.[22]

Certainly, a significant number of Americans who are not scientists feel uncomfortable about evolution in general and biological evolution in particular. Many polls have inquired into Americans' views on the subject. The results, of course, depend to a considerable degree upon just how the questions are asked. Nevertheless, it would appear that about a quarter of Americans adhere to the literal Biblical account in one form or another, perhaps a third are strongly convinced of the validity of the scientific account, and the rest — a considerable number — are ambivalent.

More germane to our concerns here is the question of Americans' attitudes toward the teaching of evolution and creationism in the public schools. The most recent poll on this subject[23] was conducted in November 1999 with results released in March 2000. Of the respondents, 66% held the view that only evolution should be taught as science; subgroups held that only evolution should be taught at all (20%), that evolution should be taught in science classes and religious creation accounts should be taught in social science or other classes (17%), and that evolution should be taught in science classes as a scientific theory with creationism mentioned as a belief (29%). The "equal time" view, that evolution and creationism should be taught together as competing views in science classes, was held by 13%, with 4% more feeling that both should be taught but uncertain as to the details. Finally, 16% believed that only creationism should be taught. Interestingly, only 1% belonged to the "don't know" category. Still more interestingly, these percentages varied over a range of less than 10% from region to region.

The Evolution of Anti-Evolution Pressures on the Public Schools

Holding that biological evolution is in conflict with religion and conducive to immorality, anti-evolutionists have unsurprisingly tried in the past to interdict its teaching in the classroom. As we have already noted, the only anti-evolutionists to have had significant influence on K-12 public education up to the present time have been the young-earth creationists. But a long series of court decisions, including two by the U. S. Supreme Court,[24] have held that the underlying premises of creationism, however they may be cloaked in euphemisms, are religious rather than scientific and thus have no place in the public-school science classroom. Largely in response to the court decisions, creationism has itself evolved. When *Epperson v. Arkansas* struck down laws forbidding the teaching of evolution in 1968, creationists responded with a pair of curiously conflicting claims:

- Creationism and evolution are both based on articles of faith and are therefore both religion, not science.
- Creationism is a scientific approach to the study of the living world just as evolution is.

The second of these claims achieved rather more currency than the first. It became the basis for model legislation introduced in many state legislatures and passed in at least two. This "balanced-treatment" legislation required that whenever "evolution science" was taught, "creation science" had to be taught on an equal footing as an equally valid, competing explanation of the living world. It was further argued that "scientific creationism" was independent of "biblical creationism," although completely compatible with the latter. A series of court decisions, culminating in a 1987 Supreme Court ruling, declared that this argument was an attempt to veil religion as

science.[25] In particular, creation implies a creator and that is a religious concept. For this and related reasons, the courts held that "creation science" was not science and had no place in the science classroom, although creation stories could certainly take their place in history, social science, and literature studies.

The failure of "creation science" to gain acceptance by the Supreme Court led to the reemergence of a strand of creationism known as "intelligent design" creationism. Proponents of this view argue that some biological processes and structures are so complex that they cannot have arisen through variation and natural selection, and therefore must have been created by an "intelligent designer." The intelligent-design approach is vehemently opposed by the young-earthers. But as we have already noted, it is gaining popularity although it has not yet had much influence on state science standards.

Appendix B gives more specifics concerning the claims and tactics of creationists. For a very detailed history of anti-evolution legislation, see the Bibliography, especially Ronald Numbers's fine 1992 book, *The Creationists: The Evolution of Scientific Creationism.*

How Do Science Standards Reflect Creationist Pressures?

States that respond to creationist pressure do so in different ways and to varying degrees. The responses ordinarily take one or more of the following forms:

- The standards include many of the central principles of evolution — usually briefly — but the word *evolution* is carefully avoided. Inaccurate and misleading euphemisms such as "change over time" are used instead of the E-word.
- Biological evolution is simply ignored. Geological evolution, the history of the solar system, and cosmology may well be treated, often even employing the word evolution. Fossils are sometimes mentioned, but only in the context of geology, not biology.
- Evolution of plants and animals is treated to some degree but human evolution is ignored.
- All scientific discussions that imply an old earth or universe are deleted. Kansas is the only state to do this completely, but Mississippi, Tennessee, and West Virginia come close.
- Creationist jargon is used.
- In Alabama, all textbooks are required to carry a disclaimer that calls evolution "controversial" and labels it "a theory, not a fact." The disclaimer also cites a number of other standard creationist ploys. The details of this approach are discussed below.
- Some or all of the historical sciences are treated lightly but no attempt is made to elucidate the connections among them.

The grades given in this report for the treatment of evolution in state science standards reflect the extent to which states have resorted to the anti-evolution tactics sketched above. States get lower grades if they avoid mention of the word evolution, if they ignore human evolution or biological evolution, if they use creationist jargon, *etc.* A more detailed explanation of the grading criteria appears in the next section.

Evaluation of State Standards

Forty-nine of the fifty states and the District of Columbia have published science standards (also sometimes called frameworks, curriculum guides, *etc.*) As a matter of policy, Iowa does not write statewide academic standards in any subjects. The documents reviewed are listed in Appendix C.

The treatments of evolution in the fifty science standards fall into six categories, which we have denoted A, B, C, D, F, and F-minus to correspond with traditional letter grades. Table 3 below shows the distribution of the grades.

The grades were determined by establishing a set of eight criteria consistent with the principles set forth in the section entitled "How Do Good Standards Treat Biological Evolution?" Each state's standards were evaluated according to the criteria listed in Table 4 on p. 12, and the standards were assigned points based on how they handled each criterion. Table 4 shows how many points each state received for each of the eight criteria.

For each state, the points assigned for these eight criteria were added. (The maximum possible total is 110 points; the totals are given in column 10 of the table.) The totals were then normalized to the familiar 100-point scale (*i.e.* converted to percentages), which are shown in column 11 of Table 4. Finally, letter grades were assigned as follows:

A = 90-100	Treatment of evolution is excellent or very good
B = 80-89	Treatment of evolution is good
C = 60-79	Treatment of evolution is satisfactory
D = 40-59	Treatment of evolution is unsatisfactory
F = 0-39	Treatment of evolution is useless or absent

F-minus = negative values. Treatment of evolution is disgraceful.

Brief comments on the strengths and weaknesses of the standards of different states appear in Table 5 on pp. 14-15. In addition to showing the grade given to the standards for their treatment of evolution, Table 5 also shows the grade that was given to each state's science standards as a whole when the standards were evaluated in 1999.

A. Very Good to Excellent

Ten states treat evolution very well or excellently. That is, they introduce at least some of the basic processes of biological evolution early, building on them later, and they make evolution the centerpiece of the life sciences. Evolution is treated in depth in Grades 9-12, and in some cases earlier. Many of these states also treat the historical sciences seamlessly. These states are California, Connecticut, Delaware, Hawaii, Indiana, New Jersey, North Carolina, Pennsylvania, Rhode Island, and South Carolina.[26] All but Delaware and South Carolina also treat human evolution explicitly, and all do at least a satisfactory job of treating the other historical sciences and the connections among them. South Carolina treats human evolution implicitly. However, as we have noted in an earlier study,[27] extra-solar-system astronomy is too often limited to the upper grades. Earth history usually gets better treatment but there is room for improvement in many cases.

Instead of illustrations here of top-quality

Table 3. Distribution of Grades for Treatment of Evolution

GRADE	A	B	C	D	F	F-
NUMBER OF STATES	10	14	7	6	12	1
STATES	CA, CT, DE, HI, IN, NJ, NC, PA, RI, SC	AZ, CO, DC, ID, MA, MI, MN, MO, MT, OR, SD, UT, VT, WA	LA, MD, NE, NV, NM, NY, TX	AK, AR, IL, KY, VA, WI	AL, FL, GA, ME, MS, NH, ND, OH, OK, TN, WV, WY	KS

state standards, the reader is again encouraged to examine Appendix A, which offers excerpts from two exemplary (albeit quite different) treatments of evolution drawn from the standards of California and North Carolina.

B. Good

Thirteen states and the District of Columbia handle evolution well but do not fulfill all the criteria for a first-rate treatment. They are Arizona, Colorado, the District of Columbia, Idaho, Massachusetts, Michigan, Minnesota, Missouri, Montana, Oregon, South Dakota, Utah, Vermont, and Washington. As a general rule, their treatments of evolution are not as complete as those of the A-level states, and all but Michigan fail to treat human evolution explicitly. In one case (DC), the brevity of the treatment of evolution merely reflects the excessive brevity of the science standards as a whole.

Excerpts from the Oregon, Massachusetts, and Colorado standards demonstrate typical B-level achievement (see pages 18-19). Each of the three examples misses out on an A in a different way. Oregon presents good if brief material but does not elucidate the central position of evolution in the life sciences as a whole. Massachusetts—oddly—treats evolution quite explicitly in the detailed science standards, but uses incorrect terminology in the introductory material. Colorado treats human evolution only implicitly, as the excerpt shows.

C. Satisfactory

Seven states rate a C—that is, they are satisfactory but not terribly good. These states are Louisiana, Maryland, Nebraska, Nevada, New Mexico, New York, and Texas. The excerpts from the New York and Louisiana standards will serve as examples of relatively better and weaker C-level quality (see pages 20-21). Although these standards leave much to be desired, they can still serve as bases for good curricula.

D. Unsatisfactory

Six states rate an unsatisfactory D. They are Alaska, Arkansas, Illinois, Kentucky, Virginia, and Wisconsin. The reasons for these weak performances vary.

The standards of Arkansas and Wisconsin do not balk at use of the "E-word." These standards mention evolution in the context of biology but treat it so skimpily that the coverage is useless or nearly so. They ignore human evolution altogether. It is hard to know the reason for this stratagem. Possibly, the standards writers hope to achieve a degree of scientific respectability while not ruffling creationist feathers. Or the stratagem may be based on the expectation that, if mention of evolution is limited to a few statements tucked away at the highest possible grade, most students will never "get to it." Either way, the student is the loser.

Illinois and Kentucky avoid the dreaded "E-word," at least in the context of biology; Virginia comes close to doing the same. This naturally puts the standards at a great disadvantage in discussing evolution. Virginia makes the best of a bad job. Illinois and Kentucky do not even rise to that level. The situation is evocative of the old theater superstition according to which mention of the title of Shakespeare's *Macbeth* brings bad luck. In order to avoid the "M-word," actors speak of "the Scottish play," or "the play about Scotland that I've never read." In the theater, this conceit can be taken lightheartedly. After all, the marquee still says "Macbeth." Unfortunately, the result of such dodging is more damaging in science, where terms have precise and well-defined meanings. Some of these states substitute the phrase "change over time," but that does not mean the same thing.[25] "Evolution" has a different and broader meaning than the euphemisms used to replace it. Using the word "evolution" in the geological or cosmological but not the biological context, as some states do, reveals the hypocrisy of the approach—a point which will not be lost on students.

[Discussion of states graded F and F- is continued on p. 16.]

Table 4: Scoring Summary for Treatment of Evolution

State	Legal Status	Biological Evolution Treated	Human Evolution Treated	Geological Evolution Treated	Origin of Life Treated	Treatment Overall	Bias Disclaimer	Total Points	Percentage	Grade
Alabama	0	20	0	10	5	0	0	-25	10	9%	F
Alaska	20	20	0	10	2.5	0	0	0	52.5	48%	D
Arizona	20	30	0	20	10	10	0	0	90	82%	B
Arkansas	20	10	0	20	10	0	0	0	60	55%	D
California	20	40	10	20	10	10	0	0	110	100%	A
Colorado	20	30	5	20	10	10	0	0	95	86%	B
Connecticut	20	40	10	20	10	10	0	0	110	100%	A
Delaware	20	40	0	20	10	10	0	0	100	91%	A
District of Columbia	20	30	5	20	2.5	10	0	0	87.5	80%	B
Florida	0	10	0	5	2.5	0	0	0	17.5	16%	F
Georgia	10	10	0	5	2.5	0	-20	0	7.5	7%	F
Hawaii	20	30	10	20	10	10	0	0	100	91%	A
Idaho	20	30	0	20	10	10	0	0	90	82%	B
Illinois	0	20	0	10	10	10	0	0	50	45%	D
Indiana	20	40	10	20	10	10	0	0	110	100%	A
Kansas	0	0	0	0	0	0	-20	0	-20	-18%	F-
Kentucky	0	20	0	20	10	10	0	0	60	55%	D
Louisiana	20	20	0	20	10	0	0	0	70	64%	C
Maine	5	10	5	5	2.5	5	0	0	32.5	30%	F
Maryland	20	30	0	20	10	5	0	0	85	77%	C
Massachusetts	20	40	0	20	10	5	-5	0	90	82%	B
Michigan	20	30	10	20	2.5	10	0	0	92.5	84%	B
Minnesota	20	30	5	20	10	10	0	0	95	86%	B
Mississippi	0	0	0	5	0	0	0	0	5	5%	F
Missouri	20	30	0	20	10	10	0	0	90	82%	B
Montana	20	30	0	20	10	10	0	0	90	82%	B
Nebraska	20	30	5	20	2.5	5	-10	0	72.5	66%	C
Nevada	20	40	0	10	5	2.5	0	0	77.5	70%	C
New Hampshire	10	10	0	5	0	0	0	0	25	23%	F
New Jersey	20	40	10	20	10	10	0	0	110	100%	A
New Mexico	20	30	5	20	5	0	0	0	80	73%	C
New York	20	30	5	5	10	10	-5	0	75	68%	C
North Carolina	20	40	10	20	10	10	0	0	110	100%	A
North Dakota	5	10	0	10	5	0	-20	0	10	9%	F
Ohio	0	10	5	5	2.5	10	0	0	32.5	30%	F
Oklahoma	0	20	0	5	2.5	0	0	0	27.5	25%	F
Oregon	20	30	0	20	10	10	0	0	90	82%	B
Pennsylvania	20	30	10	20	10	10	0	0	100	91%	A
Rhode Island	20	40	10	20	10	10	0	0	110	100%	A
South Carolina	20	40	5	20	10	10	0	0	105	95%	A
South Dakota	20	30	0	20	10	10	0	0	90	82%	B
Tennessee	0	0	0	2.5	0	0	0	0	2.5	2%	F
Texas	20	20	0	20	10	0	0	0	70	64%	C
Utah	20	30	0	20	10	10	0	0	90	82%	B
Vermont	20	30	5	20	10	10	0	0	95	86%	B
Virginia	5	20	0	20	10	0	0	0	55	50%	D
Washington	20	30	5	20	10	10	0	0	95	86%	B
West Virginia	0	0	0	0	2.5	0	0	0	2.5	2%	F
Wisconsin	20	30	0	10	5	5	-10	0	60	55%	D
Wyoming	20	10	0	5	2.5	2.5	0	0	40	36%	F
Maximum Points	20	40	10	20	10	10	-20	-25			

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Guide to Table 4

In each column, a state's science standards are assigned points depending on how they deal with a particular criterion. This guide explains what the criteria are and how the points were assigned.

Column 2, E-word used? :

20: The word evolution is used whenever called for. There are likely one or more major sections entitled Evolution.
10: The word is used, but not often. It may well appear more frequently in earth-science or astronomy sections than in life-science sections.
5: The word is used just once, or appears only in one or a few places where it might easily be missed.
0: The word does not appear

Column 3: Biological evolution treated? :

40: The treatment is thorough and detailed, and permeates the treatment of the historical sciences rather than being confined to a single section. At least some of the basic underlying concepts essential to understanding evolution are introduced at early grades.
30: Evolution is treated straightforwardly but perhaps briefly and/or not in the earlier grades. The overarching importance of evolution, especially in the life sciences, is not stressed.
20: Evolution is mentioned briefly but the criteria for higher scores are not met.
10: Evolution is mentioned, but not in a way that encourages clarification of its role in the life sciences.
0: No treatment

Column 4: Human evolution treated?

A number of states that do a sound job of presenting biological evolution never tie it to people: those that do, either explicitly or implicitly, receive what amounts to extra credit here.

10: There is at least some direct mention of human evolution.
5: Human evolution is not mentioned explicitly but is implied in statements to the effect that biological concepts are applicable to humans as to other animals.
2.5: Human evolution is very weakly implied
0: No treatment.

Column 5: Geological evolution treated?

20: Substantial attention is devoted to the history of the earth and to such mechanisms as plate tectonics and continental drift, usually at early or middle grades
10: The treatment of earth history is good but less than ideally thorough, with treatment usually beginning at the middle or even the high-school level.
5: Words such as plate tectonics and continental drift are used, but in a limited way and/or at the high-school level only.
2.5 Mention only in passing, at the high-school level only.
0 No treatment.

Column 6: Cosmology treated?

10: There is significant discussion of the Big Bang, of stellar evolution, of the Hertzsprung-Russell diagram, and perhaps of quasars, neutron stars, black holes, and other cosmologically significant objects, usually beginning at the middle-school or even the primary level.
5: There is a brief treatment, usually only at the high-school level.
2.5: There is a single statement, at the high-school level, of the form Students will be able to discuss the Big Bang and other theories of the origin of the universe.
0: No treatment.

Column 7: Connections among the historical sciences treated?

10: Significant exposition of the seamless connection among the life, earth, and space sciences. Examples: discussion of the essential role of living things in the transition of the earth's atmosphere from reducing to oxidizing and the consequence of this for the evolution of life; the use of radioactive dating in geology and biology; the presence of iridium at the K-T boundary. These ideas are typically introduced at the middle or early grades.
5: Brief treatment with few examples, usually confined to the upper grades.
2.5: Minimal treatment.
0: No treatment.

Column 8: Creationist jargon used?

States that use creationist jargon lose points; they are docked for undermining the sound treatment of evolution.

-20: Extensive use of the kinds of language used by creationists to cast doubt on the theory of evolution, for instance, describing evolution as a controversial theory among scientists, conflating the scientific meaning of the word theory with its everyday meaning, misusing the term micro-evolution to describe known examples of evolution that result in diverse species, etc. (Many other examples are discussed in the Alabama excerpts and Endnotes 32 through 45, and in the excerpts from the Massachusetts and New York standards.)
-10: Less extensive use of such terminology.
-5: Brief, probably inadvertent use of the terminology.
0: No use.

Column 9: Disclaimer?

States that require a disclaimer lose points; they are docked for subverting the sound treatment of evolution.

-25: Yes. The state requires a statement that attempts to deny what its textbooks are teaching.
0: No use.

Table 5: State Report Cards on the Treatment of Evolution

State	Grade for Evolution	Grade for Overall Science Standards	Description
Alabama	F	D	Close reading of the standards indicates that their authors knew much more about evolution than they felt free to impart to their readers. A deceptive "disclaimer" on the textbooks makes things even worse.
Alaska	D	-	Too meáger to fulfill the mission of standards, which is why standards as a whole were not rated. Evolution is treated as well as any other subject of importance—but all are far too thin. Earth history is slighted; cosmology is almost absent.
Arizona	B	A	A solid though not comprehensive treatment of evolution. Especially laudable is the introduction of basic ideas in early grades.
Arkansas	D	F**	Although inadequate in its present form, the treatment of evolution could readily be expanded to provide a satisfactory treatment in the life sciences as it already does for the earth and universe.
California	A	A	Very detailed, and well organized. Beginning in early grades, conveys concepts, content, and methods of science. Possibly too demanding.
Colorado	B	D	A good treatment that could readily be made into an excellent one.
Connecticut	A	B**	Although relatively brief, this document does an exemplary job of integrating the historical sciences—especially the life sciences—around evolution.
Delaware	A	A	Begins to introduce evolutionary ideas at the K-3 level and builds solidly from there on. No treatment of human evolution
Dist. of Columbia	B	-*	A brief treatment that covers all the essentials.
Florida	F	F	Extensive standards that skim lightly over biological and geological evolution without ever mentioning the word. Not satisfactory.
Georgia	F	F	Though the standards document is long, the treatment of evolution is so skimpy as to be useless. Creationist jargon makes matters worse.
Hawaii	A	D	The standards document is too brief but evolution takes a pivotal position. Human evolution is well treated.
Idaho	B	-*	A good treatment of evolution, with the foundations laid early.
Illinois	D	B	The treatment of evolution is an embarrassment; the E-word is carefully avoided.
Indiana	A	A	An exemplary, straightforward treatment.
Kansas	F-	F**	A disgraceful paean to antiscience.
Kentucky	D	D	It appears that young Kentuckians are to be sheltered from any exposure to evolution and other dangerous words and theories.
Louisiana	C	C	Brief but satisfactory. Dodges human evolution and doesn't convey the unity of the sciences.
Maine	F	D	A useless treatment of evolution in a generally inadequate document.
Maryland	C	D	A satisfactory approach that could readily be made into an excellent one.
Massachusetts	B	A**	Good general treatment of evolution marred by the incursion of creationist jargon. Human evolution is ignored.
Michigan	B	D	A well-organized treatment of evolution, although cosmology is short-changed.
Minnesota	B	A	Solid and extensive coverage.
Mississippi	F	F	Mississippi appears determined to keep evolution outside its borders.
Missouri	B	C	A solid treatment, except for human evolution, which is ignored.
Montana	B	D	Brief but well organized, as far as it goes; human evolution is ignored.
Nebraska	C	B	A decent treatment of evolution marred by the incursion of creationist notions.
Nevada	C	C	Fine treatment of biological evolution, except for human evolution. The other historical sciences are short-changed.
New Hampshire	F	F	A bit of this, a bit of that, but nothing useful.

Table 5: State Report Cards on the Treatment of Evolution (continued)

State	Grade for Evolution	Grade for Overall Science Standards	Description
New Jersey	A	A	Excellent: Well-organized, solid content.
New Mexico	C	F	Satisfactory treatment of evolution shines within a generally skimpy document.
New York	C	C	This otherwise satisfactory document suffers from sloppy organization and inclusion of creationist jargon. It could easily be revised into a first-rate set of standards.
North Carolina	A	A	A model of completeness of good organization. Begins in middle school and conveys a well-integrated picture of the historical sciences in Grades 9-12.
North Dakota	F	F**	A minimal treatment of evolution rendered useless by the insinuation of creationist views.
Ohio	F	B	Evolution treated here as if it were not proper conversation in polite company. The E-word is avoided and the evolutionary process occupies a near-negligible part of an extensive document.
Oklahoma	F	F**	We don't use that word in Oklahoma! As for "biological adaptation," we discuss that as little as possible. How will Oklahoma children learn where all that petroleum came from?
Oregon	B	B	Solid if uninspired coverage of the subject—except for human evolution, which is ignored.
Pennsylvania	A	-*	Thorough if somewhat sketchy coverage, beginning in the primary grades and including human evolution.
Rhode Island	A	A	Extensive, superbly organized treatment of evolution in all the historical sciences. Evolution permeates most or all areas of the life sciences and the other historical sciences.
South Carolina	A	B*	A thorough and challenging treatment of evolution, well integrated across the life sciences and historical sciences. Mostly confined to high school, however.
South Dakota	B	B	Given the overall brevity of the standards, evolution is treated satisfactorily.
Tennessee	F	F**	It seems the Scopes trial is still underway in Tennessee. None of the sketchy biology coverage makes sense—but the rest of the standards are nearly useless, too.
Texas	C	C**	Brief but satisfactory, like Texas's science standards in general. No human evolution.
Utah	B	B	Satisfactory coverage of biological evolution, but only in Grades 9-12. The implications for the life sciences are not made clear, but earth and space sciences are handled quite well.
Vermont	B	B	Though the standards are brief, attention is given to the central position of evolution in the life sciences. Cosmology is treated sketchily.
Virginia	D	D	Biological evolution is a hot potato in the Virginia standards, touched as briefly as possible. The other historical sciences are handled more courageously.
Washington	B	B	Brief, straightforward account of evolution. A good basis for curriculum building.
West Virginia	F	F	The words "natural selection" occur once, at Grade 10. The treatment of the life sciences is useless.
Wisconsin	D	C	The approach to evolution starts early (Grades 3-6) but at the high-school level it is confused and mixed with nonscientific matters.
Wyoming	F	F**	It is hard to tell just what the student is expected to know. There is a bit about biological evolution at Grades 8 and 11, nothing more, despite a fine bibliography of sources.

Note: Standards were graded for their coverage of evolution in the summer of 2000; for this purpose, the most up-to-date state standards that could be obtained were evaluated. Overall science standards were evaluated during 1999, in some cases using earlier documents.

* Grades appearing in the two columns are based on substantively different versions of their states' academic standards.

** Grades appearing in the two columns are based on different versions of the standards but, at least with regard to evolution, the documents do not differ significantly.

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F. Useless or Absent

Twelve states fail so thoroughly to teach evolution as to render their standards totally useless. These are Alabama, Florida, Georgia, Maine, Mississippi, New Hampshire, North Dakota, Ohio, Oklahoma, Tennessee, West Virginia, and Wyoming.

Nine of these states—Alabama, Florida, Georgia, Maine, New Hampshire, North Dakota, Ohio, Oklahoma, and Wyoming—attempt to teach a little something about evolution but miss the mark completely (see p. 22). Five sedulously avoid or (in one case) carefully conceal the E-word, at least in the context of biology. These states are Alabama, Florida, North Dakota, Ohio, and Oklahoma. Most employ the misleading euphemism "change over time"; Oklahoma prefers "biological adaptation." Ironically, a few of these states use the word "evolution" freely in the context of geology or cosmology.

Curiously, Ohio, which carefully avoids the use of the E-word even in non-biological contexts, touches on human evolution by inference, though few readers are likely to be in a position to catch it.[29]

Alabama is a special case among the states with failing grades. About four years ago, the State Board of Education mandated that a sticker bearing a disclaimer be pasted in the front of every science textbook that deals with evolution. Remarkably, the disclaimer cites many of the most common and most thoroughly discredited arguments used by creationists in objecting to evolution. For that reason only, it is worth perusing. (See box on page 23.)

In 1999, the Oklahoma board followed Alabama's lead, directing that the identical disclaimer be printed in the front matter of every textbook. Most publishers reluctantly expressed their willingness to go along with this rule; a few preferred that their books not be used. However, the attorney general issued an opinion to the effect that the board had exceeded its legal authority, and no action has been taken. Similar proposals in other states have stalled at various stages of the legislative or administrative process.

Three states—Mississippi, Tennessee, and West Virginia—have adopted the view that, if you completely ignore evolution the creationist politicians will leave you alone, and that if you completely ignore evolution you can teach science anyway. Mississippi and Tennessee allow a smidgen of evolution to creep into geology; West Virginia into cosmology. None of these states, of course, countenances the use of the E-word. One example will suffice; the text box on page 22 shows everything the Tennessee standards have to say about anything approximating evolution.

F-minus. Disgraceful

Kansas is a special case, unique in the extremity of its exclusion of evolution from statewide science standards. As already noted, many states either avoid or skirt discussion of biological evolution, or avoid the use of the E-word in the biological context. Kansas, however, avoids all discussion of the age of the earth or the universe, or any other topics touching on the history of the earth or universe. In addition, young-earth creationist jargon has been injected into the standards. To give just two examples of many:

- Natural selection can maintain or deplete genetic variation but does not add new information to the genetic code.
- Using examples of *microevolution* [emphasis added], such as Darwin's finches or the peppered moths of Manchester ...[30]

The gross subversion of the Kansas standards is especially regrettable because the original document submitted for Board approval was compiled over a year by a distinguished committee of twenty-seven teachers, scientists, and other experts, and was a fine basis for science education. A substitute written under the auspices of a young-earth creationist organization was so outrageous that it was not adopted. Instead, the Board took the committee draft and expurgated it, removing all references to biological evolution, the age of the universe, and anything that could be construed as undergirding a universe more than a few thousand years old (such as radioactive dating.) As noted above, creationist jargon was inserted as well. Further examples of the distortions introduced are given in *Standards 2000*. A word-by-word analysis of the deletions, additions, and changes made to the committee

document by the Board of Education is available on the Internet.[31]

Five of the ten seats on the Kansas Board of Education were up for reelection in the state primary election of 1 August 2000. The election was remarkable for the interest it generated on the Republican side;[32] one creationist candidate spent $90,000 and her successful opponent spent $36,000—sums unheard of in school-board elections. The results of that election were such that, regardless of the outcome of the November general election, the majority on the state board will change from 6-4 in favor of creationism to somewhere between 8-2 and 6-4 in favor of a scientific approach. As the election hinged almost exclusively on the issue raised by the published science standards, it is likely that a very considerable improvement will occur when the Board meets in January 2001. Should the Board decide to return to the version submitted by the drafting committee, Kansas's grade will rise from F-minus to the A that the committee draft would warrant.

Sample Standards

Standards receiving a grade of A

Please see appendix A for examples from California and North Carolina

Standards receiving a grade of B

Oregon (B)

Oregon does a good but not outstanding job of covering evolution. Here is what the Oregon Content Standards For Science have to say about evolution:

Describe the principles of natural selection and adaptation:
Grade 3: Identify how some animals gather and store food, defend themselves, and find shelter.
Grade 5: Describe how adaptations help an organism survive in its environment.
Students will: identify how an organism s fur, color, shape, size, etc, adapt to its specific environment.
Identify how and why unique animal and plant structures and behaviors are adaptive. Examples might include a plant developing thorns for protection from birds and larger herbivores; an octopus copying the color and texture of its surroundings for camouflage; vultures spreading their wings toward the sun to kill bacteria acquired when feeding on carrion.
Grade 8: Describe and explain the theory of natural selection as a mechanism for change over time.
Students will: Cite which variations within a population would be naturally selected for a specific environment and why.
Explain how random variations in species can be preserved through natural selection. Examples include camouflage, long necks on giraffes. Describe conditions that might cause a species to become endangered or extinct.
Differentiate between adaptive or non-adaptive variations within a species with respect to the environment.
Grade 10: Analyze how living things have changed over geological time using fossils and other evidence.
Students will: Recognize that over time, natural selection may result in speciation ... as well as the development of sub-species.
Recognize that natural selection and its evolutionary consequences provide scientists with an explanation for the fossil record as well as an explanation for the striking molecular similarities among varied species.
Explain lines of evidence showing that two specific organisms are related by common ancestors.
Explain how biological evolution can account for the diversity of species developed over time.
Grade 12: Apply knowledge and concepts from the life sciences to investigations, projects, and new learning (within both the life sciences and within other domains and disciplines.)

Source: Teaching and Learning Standards: Science, September 1999

Massachusetts (B)

In this excerpt from the Massachusetts document, the first two uses of the term natural selection (emphasis added) are incorrect; the third is correct but incomplete. It is unclear whether the misuse of the term is intentional euphemism, simple scientific misunderstanding, or a mere editorial slip. The very good treatment of evolution in the detailed standards suggests the last.

> The Life Science (Biology) Learning Standards for High School
> At the high school level, the students study the molecular basis of life by looking at the processes occurring in cells. In particular, these students learn that the DNA molecule provides the basis for understanding *natural selection*. They learn that variation is inherited, the unit of inheritance being the gene. It is the inherited traits that provide the variation on which natural and manipulated selection act.
> The theory of *natural selection* is central to the intellectual history of the 20th century, but is also fundamental to understanding modern biology. It provides a framework for explaining why there are so many different kinds of organisms on earth; why organisms of distantly related species share biochemical, anatomical, and functional characteristics; why species become extinct; and it helps us to explain how different kinds of organisms are related to one another.
>
> Today, diversity and change not only occur because of *natural selective* pressures, but also because of human manipulations of cells. ...

Source: Science & Technology/Engineering Framework, revised draft August 1999

Colorado (B)

Colorado treats human evolution only implicitly. Here is the closest the standards get to the subject:

> Optional for students at Grades 9-12:
>
> determining the degree of kinship between organisms or species from estimations of the similarity of their nucleic acid sequences, which often closely match classifications based on anatomical similarities; and explaining how the rate of environmental change may exceed the capacity of organisms to respond to change, leading to the extinction of species.

Source: Model Content Standards, June 1995

Standards receiving a grade of C

New York (C)

To its credit, New York does an overall decent job of treating evolution but waffles on human evolution and shortchanges earth history. Moreover, a bit of commonly encountered creationist jargon has crept into its standards. We find,

According to many scientists, biological evolution occurs through natural selection and, Billions of years ago, life is thought by many scientists to have begun as simple, single-celled organisms. Aside from the syntactical tangle of the second statement, the implication is that a significant group of qualified scientists believes otherwise. That, of course, distorts the true state of affairs. And, although single-celled organisms must have existed before multi-celled organisms, it is not at all clear what beginning life looked like. Nor is this germane to the field of biological evolution, strictly defined, which is concerned with the evolution of life from the first forms. Judging from the context, it may well be that these phrases survived from earlier drafts through editorial slips rather than by design. If that is so, it may not be a difficult task to make significant improvement.

3.1p. Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on structural similarities and evolutionary relationships.

3.1q. Species is the most fundamental unit of classification.

3.1r. The degree of kinship between organisms or species can be estimated from the similarity of their DNA sequences; this similarity often closely matches organisms or species classification based on anatomical similarities.

PERFORMANCE INDICATOR 4.1 Explain how organisms, including humans, reproduce their own kind.

4.1f. The structures and functions of the human female reproductive system, as in other mammals, are designed to produce gametes in ovaries, allow for internal fertilization, support the internal development of the embryo and fetus in the uterus, and provide nutrition through milk for the newborn.

4.1g. The structures and functions of the human male reproductive system, as in other mammals, are designed to produce gametes in testes and make possible the delivery of these gametes for fertilization.

Source: Mathematics, Science & Technology Guide

Louisiana (C)

Following is the entire treatment of evolution in the Louisiana standards. Although somewhat sketchy, it can serve as a basis for curriculum and textbook development. Unfortunately, there is very little groundwork laid for this material in earlier grades.

Benchmarks 9-12:
Life Science: C. Biological Evolution

LS-H-C1. exploring experimental evidence that supports the theory of the origin of life;
LS-H-C2. recognizing the evidence for evolution;
LS-H-C3. discussing the patterns, mechanisms, and rate of evolution;

Earth and Space Science: C. The Origin and Evolution of the Earth System

ESS-H-C1. explaining the formation of the solar system from a nebular cloud of dust and gas;
ESS-H-C2. estimating the age of the Earth by using dating techniques;
ESS-H-C4. examining fossil evidence as it relates to the evolution of life and the resulting changes in the amount of oxygen in the atmosphere;
ESS-H-C5. explaining that natural processes and changes in the Earth system may take place in a matter of seconds or develop over billions of years.

D. The Origin and Evolution of the Universe

ESS-H-D1. identifying scientific evidence that supports the latest theory of the age and origin of the universe;
ESS-H-D2 describing the organization of the known universe;
ESS-H-D3 comparing and contrasting the sun with other stars:
ESS-H-D5 describing the role of hydrogen in the formation of all the natural elements;

Source: Louisiana Science Framework, May 22, 1997

Standards receiving a grade of D

(No examples given.)

Standards receiving a grade of F

New Hampshire (F)

New Hampshire barely mentions evolution. For this very poor treatment, it receives an F. The following excerpts constitute the entire treatment of evolution in the New Hampshire science standards:

[Life Science: Description]

Among the basic concepts in the life sciences that have personal and societal dimensions are: genetics, nutrition, evolution, behavior, reproduction, structure/function, disease, diversity, integration of life systems, life cycles, energetics, and the dynamic relationships that exist among all forms of life and the physical environment.

3a. Curriculum Standard: **Students will** demonstrate an increasing **ability to rec**ognize patterns and products **of evolu**tion, including genetic variation, specialization, adaptation, and natural selection.

[end of Grade 10]

Describe the current scientific theory relating to the origin and geologic evolution of the Earth and the solar system.

Source: K-12 Science Curriculum Framework, 1995

Tennessee (F)

Tennessee s nontreatment of evolution is an embarrassing display of ignorance:

Grades 9-12
2.1c. Mathematical symbols and anthropological [*sic*] concepts can represent the principles of Mendelian inheritance and population genetics.
2.3. Both the uniqueness and commonality of organisms affects [*sic*] the relationship within and among ecosystems. An interrelationship of predator and prey dictates great variation from ecosystem to ecosystem. Physiological and biochemical diversity is often the result of environmental influences.
2.5b. Small changes in an ecosystem can potentially effect [*sic*] the entire biosphere. develop a natural, uninhibited, rate of change. [*sic*] Some changes in organisms may be predicted using genetic inheritance and other theories of system change.

Source: Science Curriculum Grades K-12, September 1999

Alabama (F)

Alabama attempts to teach something about evolution without ever mentioning the word in its standards. Moreover, the State Board of Education has directed that a sticker containing the following text be placed in the front of every biology textbook. The text is given here; the endnotes briefly discuss the issues that it poses.

A MESSAGE FROM THE ALABAMA STATE BOARD OF EDUCATION

This textbook discusses evolution, a controversial theory some scientists present[33] as a scientific explanation for the origin of living things, such as plants, animals and humans.

No one was present when life first appeared on earth.[34] Therefore, any statement about life s origins should be considered as theory, not fact.[35]

The word evolution may refer to many types of change. Evolution describes changes that occur within a species. (White moths, for example, may evolve into gray moths.) This process is microevolution, which can be observed and described as fact. Evolution may also refer to the change of one living thing to another, such as reptiles into birds. This process, called macroevolution, has never been observed and should be considered a theory.[36] Evolution also refers to the unproven belief that random, undirected[37] forces produced a world of living things.[38] There are many unanswered questions about the origin of life which are not mentioned in your textbook,[39] including:

- Why did the major groups of animals[40] suddenly appear in the fossil record (known as the Cambrian Explosion)?[41]
- Why have no new major groups of living things appeared in the fossil record for a long time?[42]
- Why do major groups of plants and animals have no transitional forms in the fossil record?[43]
- How did you and all living things come to possess such a complete and complex set of instructions for building a living body?[44]

Study hard and keep an open mind. Some day, you may contribute to the theories of how living things appeared on earth.[45, 46]

Source: Alabama State Board of Education.

Further Analysis

The good news is that thirty-one states have satisfactory-to-excellent treatments of evolution. But only nine of these thirty-one states treat human evolution explicitly and another nine by implication; the rest do not cover human evolution at all.

The other nineteen states are in the less-than-satisfactory ranks. These states do an unsatisfactory to dreadful job of teaching evolution—in most cases to the point of making it difficult or impossible to teach the sciences properly. Ten of the nineteen cripple their treatment of evolution through sedulous avoidance of the E-word, one state uses the word only once, and one state hides it. Of these twelve states, eight attempt to teach something of evolution, but do a poor to awful job of dealing with the subject. So do all but one of the seven remaining states that receive less-than-satisfactory grades but do mention the word evolution.

Of the nineteen states receiving unsatisfactory grades, three ignore the topic of biological evolution altogether, though they may touch on geological or cosmological evolution in a minor way. One state, Kansas, not only shuns biological evolution, it also deletes all references, direct or indirect, to the age of the earth or the universe, including even radioactive decay.

As the map of Figure 1 shows, many of the poorly performing states are in the Southeast. But not all. A perusal of the map also makes clear that evolution is poorly handled by states in other parts of the country as well. Moreover, North Carolina's and South Carolina's standards are among the very best, while Louisiana's and Texas's are satisfactory if unremarkable. Good science is not simply a geographical issue. This is an important point because it is a snobbish as well as damaging misconception to shrug one's shoulders and write off the inhabitants of this or that region as incorrigible or ineducable.

Grades for Science Standards as a Whole

To what extent is the quality of the treatment of evolution correlated with the overall quality of science standards? The third column of Table 5 (on pp. 14-15) summarizes the more comprehensive evaluations made in *Standards 2000.* The detailed breakdown of states' overall science grades from *Standards 2000* can be found in Appendix D.

Simple quantitative comparison of the two columns would lead to misleadingly strong correlations, since the quality of evolution treatments was factored into the overall evaluations. Nevertheless, it is interesting to scrutinize the cases in which there is a substantial variation (*i.e.,* more than one letter-grade difference) between the two sets of ratings. There are seven such cases: Colorado, Hawaii, Illinois, Michigan, Montana, New Mexico, and Ohio.

Hawaii, Michigan, and Montana received the poor grade of D for their science standards in *Standards 2000* for the same general reason: They were too brief or sketchy to be helpful guides in curriculum planning or the kindred activities for which standards are supposed to provide a basis. In spite of this shortcoming (which could readily be remedied in all three cases) the treatment of evolution was adequate to good, as discussed above.

Colorado received its overall D mainly on the basis of its poor treatment of the physical sciences; the life sciences fared much better.

Ohio's (B) very detailed (albeit voluntary) standards deliberately dodge the historical sciences, treating them in the most cursory manner and avoiding the E-word. The treatment of the physical sciences, however, is quite good. Like Ohio, Illinois (B) dodges biological evolution and avoids the word, but treats the other historical sciences adequately.

New Mexico's (F) standards suffered in the *Standards 2000* rating on account of their poor overall organization. Evolution had originally been omitted. This omission engendered strong reaction. Consequently, at the time of the *Standards 2000* evaluation, the life sciences had emerged considerably strengthened, especially with respect to evolution. Unfortunately, the overall organization and general vagueness of the standards remain to be remedied.

Conclusions

The American public-education system is based on the concept of local control with limited oversight from the state. This arises in part from an American view of democracy and in part from an early history of widely separated schools that were mostly quite remote from state capitals. However, today in most of the country we can see a strong public consensus for quality control at the state level, and all states have a variety of mechanisms for accomplishing this. Quality control is exercised not only through curriculum standards and the newly popular statewide examinations, but also through such traditional processes as teacher certification, class size rules, compulsory education laws, and so forth. The fact that state subventions are important in the financing of school districts is, of course, a significant factor in undergirding a modicum of control. One may thus characterize American public-school governance as a modified diffuse democracy.

Democratic decisions are made by majority rule. Citizens vote with equal voice on the basis of their opinions, regardless of what those opinions are or how strongly founded in fact they may be. We believe, of course, that a well-educated electorate is an essential basis for workable democracy, and this has always been a cardinal argument for public education. But democracy cannot permeate all aspects of every social institution. It is certainly not consistent with the education process itself. Education cannot be democratic because the teacher directly supervises the progress of the students, using his or her superior knowledge and adhering to standards imposed from levels above the classroom. It is not a matter of student consensus that the Declaration of Independence dates from 1776, or that *Marbury v. Madison* was the first significant application of the theory on whose basis the Supreme Court determines the constitutionality of laws, or that the base angles of an isosceles triangle are equal.

Science is not democratic, either. In a democratic society, citizens who do not like the existing state of affairs can change it. This has happened often. (Consider, for example, the Sherman Antitrust Act, the Prohibition Amendment, and the repeal of that amendment.) But nature is not so flexible. We may find Newton's second law of motion contrary to common sense because it links acceleration, rather than velocity, to applied force. But we cannot change this; what we can do is learn how to manipulate it. We may believe it an insult to human dignity that the earth is not at the center of the universe but we cannot move it there. We may find moral or esthetic objections to the manner in which natural history unfolds but we cannot command nature to take another course.

Science is also undemocratic in the social sense that those who do not have the scientist's special knowledge, skills, and experience cannot have equal voice in achieving a scientific consensus concerning a class of phenomena.[47] The public school has no authority to impose opinions on its students. But it has the duty to explain to them the consensus of scientists on any particular issue, and the methodology by which scientists proceed to discover new knowledge and merge it into that consensus.[48]

Biological evolution is just one of the most important of many broad issues on which substantially all working scientists agree. There may be a few persons with scientific credentials who disagree, but they do not contribute to the progress that is the hallmark of science. Analogously, on a smaller and perhaps more digestible scale, there are a few scientists who do not believe that the human immunodeficiency virus is the cause of AIDS, but they have contributed nothing to the development of the antiviral drugs that have so greatly improved the prognosis for patients over the past decade or so. It is not simply that these dissenters are wrong, because wrong answers can sometimes stimulate controversy that helps lead to correct answers. Rather, as the physicist Wolfgang Pauli liked to say, they are *not even* wrong. That is, their arguments are useless and even detrimental to the pursuit of further knowledge.

This being the case, the publication and maintenance of scientifically accurate curriculum standards is a vital quality-control function of the states. Given the far-reaching ramifications of evolution in the life sciences — to say nothing of

the other historical sciences — a complete and proper exposition of evolution is an essential constituent of state science standards. Short-changing, distorting, or omitting evolution indeed harms the teaching of the life sciences. Further, it makes it difficult for the student to come to a clear understanding of how science works. No one disputes, of course, the importance of teaching scientific literacy to the coming generation of citizens.

As primatologist Andrew J. Petto has put it, "The real objectives in science education ... are to have students learn why scientists accept evolution as the explanation for the diversity and history of life, and to understand why all the life sciences are built on this theoretical foundation. To accomplish this, we must help our students master complicated information so that they can appreciate the wonder and grandeur of this view of life, and can use this foundation for their future roles as scientifically literate citizens. It does not advance science education to waste time on non-issues."[49]

Given this state of affairs, a school district — or a state — cannot argue that it is a simple matter of democracy to advocate a scientifically unacceptable opinion because a majority or vocal minority of citizens holds that opinion. One can understand the desire of parents to raise their children to think as they do. But if the parents' belief is based on poor understanding of the content and methods of science, it is well if they hope and expect that their children will understand science better than they do. In doing so, parents will provide the means to expose the children to expertise beyond their own. Indeed, that is why most parents want to send their children to school.

About two-thirds of the states today have science standards that are consistent with this educational philosophy and teach their students accordingly. Americans owe it to the students in the other third to raise their standards to the same level. Poor education, wherever it may be, affects us all.

Appendix A: Two Model Treatments of Evolution: Excerpts From the California and North Carolina Science Standards

1. California

Note: Items marked with an asterisk are optional and are intended for advanced students.[50]

Grade 2

Life Sciences

2. a. [*Students know that* plants and animals reproduce offspring] of their own kind and that the offspring resemble their parents and one another.
   b. *Students know* the sequential stages of life cycles are different for different animals, such as butterflies, frogs, and mice.
   c. *Students know* many characteristics of an organism are inherited from the parents. Some characteristics are caused or influenced by the environment.
   d. *Students know* there is variation among individuals of one kind within a population.

Earth Sciences

3. d. *Students know* that fossils provide evidence about the plants and animals that lived long ago and that scientists learn about the past history of Earth by studying fossils.

Grade 3

Life Sciences

3. c. *Students know* living things cause changes in the environment in which they live: some of these changes are detrimental to the organism or other organisms, and some are beneficial.
   d. *Students know* when the environment changes, some plants and animals survive and reproduce; others die or move to new locations.
   e. *Students know* that some kinds of organisms that once lived on Earth have completely disappeared and that some of those resembled others that are alive today.

Earth Sciences

4. a. *Students know* some changes in the earth are due to slow processes, such as erosion, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes.

Grade 6

Focus on Earth Science

1. a. *Students know* evidence of plate tectonics is derived from the fit of the continents; the location of earthquakes, volcanoes, and midocean ridges; and the distribution of fossils, rock types, and ancient climatic zones.
   b. *Students know* Earth is composed of several layers: a cold, brittle lithosphere; a hot, convecting mantle; and a dense, metallic core.
   c. *Students know* lithospheric plates the size of continents and oceans move at rates of centimeters per year in response to movements in the mantle.
   d. *Students know* that earthquakes are sudden motions along breaks in the crust called faults and that volcanoes and fissures are locations where magma reaches the surface.
   e. *Students know* major geologic events, such as earthquakes, volcanic eruptions, and mountain building, result from plate motions.

Grade 7

Focus on Life Science

Evolution

3. Biological evolution accounts for the diversity of species developed through gradual processes over many generations. As a basis for understanding this concept:
   a. *Students know* both genetic variation and environmental factors are causes of evolution and diversity of organisms.
   b. *Students know* the reasoning used by Charles Darwin in reaching his conclusion that natural selection is the mechanism of evolution.
   c. *Students know* how independent lines of evidence from geology, fossils, and comparative anatomy provide the bases for the theory of evolution.
   d. *Students know* how to construct a simple branching diagram to classify living groups of organisms by shared derived characteristics and how to expand the diagram to include fossil organisms.
   e. *Students know* that extinction of a species occurs when the environment changes and that the adaptive characteristics of a species are insufficient for its survival.

Earth and Life History (Earth Science)

4. Evidence from rocks allows us to understand the evolution of life on Earth. As a basis for understanding this concept:
   a. *Students know* Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.
   b. *Students know* the history of life on Earth has been disrupted by major catastrophic events, such as major volcanic eruptions or the impacts of asteroids.
   c. *Students know* that the rock cycle includes the formation of new sediment and rocks and that rocks are often found in layers, with the oldest generally on the bottom.
   d. *Students know* that evidence from geologic layers and radioactive dating indicates Earth is approximately 4.6 billion years old and that life on this planet has existed for more than 3 billion years.
   e. *Students know* fossils provide evidence of how life and environmental conditions have changed.
   f. *Students know* how movements of Earth's continental and oceanic plates through time, with associated changes in climate and geographic connections, have affected the past and present distribution of organisms.
   g. *Students know* how to explain significant developments and extinctions of plant and animal life on the geologic time scale.

Grades 9-12

Earth's Place in the Universe

1. Astronomy and planetary exploration reveal the solar system's structure, scale, and change over time. As a basis for understanding this concept:
   a. *Students know* how the differences and similarities among the sun, the terrestrial planets, and the gas planets may have been established during the formation of the solar system.
   b. *Students know* the evidence from Earth and moon rocks indicates that the solar system was formed from a nebular cloud of dust and gas approximately 4.6 billion years ago.
   c. *Students know* the evidence from geological studies of Earth and other planets suggest that the early Earth was very different from Earth today.
   d. *Students know* the evidence indicating that the planets are much closer to Earth than the stars are.
   e. *Students know* the Sun is a typical star and is powered by nuclear reactions, primarily the fusion of hydrogen to form helium.
   f. *Students know* the evidence for the dramatic effects that asteroid impacts have had in shaping the surface of planets and their moons and in mass

extinctions of life on Earth.

g.* *Students know* the evidence for the existence of planets orbiting other stars.

2. Earth-based and space-based astronomy reveal the structure, scale, and changes in stars, galaxies, and the universe over time. As a basis for understanding this concept:
   a. *Students know* the solar system is located in an outer edge of the disc-shaped Milky Way galaxy, which spans 100,000 light years.
   b. *Students know* galaxies are made of billions of stars and comprise most of the visible mass of the universe.
   c. *Students know* the evidence indicating that all elements with an atomic number greater than that of lithium have been formed by nuclear fusion in stars.
   d. *Students know* that stars differ in their life cycles and that visual, radio, and X-ray telescopes may be used to collect data that reveal those differences.
   e.* *Students know* accelerators boost subatomic particles to energy levels that simulate conditions in the stars and in the early history of the universe before stars formed.
   f.* *Students know* the evidence indicating that the color, brightness, and evolution of a star are determined by a balance between gravitational collapse and nuclear fusion.
   g.* *Students know* how the red-shift from distant galaxies and the cosmic background radiation provide evidence for the "big bang" model that suggests that the universe has been expanding for 10 to 20 billion years.

Dynamic Earth Processes

3. Plate tectonics operating over geologic time has changed the patterns of land, sea, and mountains on Earth's surface. As the basis for understanding this concept:
   a. *Students know* features of the ocean floor (magnetic patterns, age, and sea-floor topography) provide evidence of plate tectonics.
   b. *Students know* the principal structures that form at the three different kinds of plate boundaries.
   c. *Students know* how to explain the properties of rocks based on the physical and chemical conditions in which they formed, including plate tectonic processes.
   d. *Students know* why and how earthquakes occur and the scales used to measure their intensity and magnitude.
   e. *Students know* there are two kinds of volcanoes: one kind with violent eruptions producing steep slopes and the other kind with voluminous lava flows producing gentle slopes.
   f.* *Students know* the explanation for the location and properties of volcanoes that are due to hot spots and the explanation for those that are due to subduction.

Energy in the Earth System

6. c. *Students know* how Earth's climate has changed over time, corresponding to changes in Earth's geography, atmospheric composition, and other factors, such as solar radiation and plate movement.

Structure and Composition of the Atmosphere

8. Life has changed Earth's atmosphere, and changes in the atmosphere affect conditions for life. As a basis for understanding this concept:
   a. *Students know* the thermal structure and chemical composition of the atmosphere.
   b. *Students know* how the composition of Earth's atmosphere has evolved over geologic time and know the effect of outgassing, the variations of carbon dioxide concentration, and the origin of atmospheric oxygen.

Biology/Life Sciences

Evolution

7. The frequency of an allele in a gene pool of a population depends on many factors

and may be stable or unstable over time. As a basis for understanding this concept:

a. *Students know* why natural selection acts on the phenotype rather than the genotype of an organism.
b. *Students know* why alleles that are lethal in a homozygous individual may be carried in a heterozygote and thus maintained in a gene pool.
c. *Students know* new mutations are constantly being generated in a gene pool.
d. *Students know* variation within a species increases the likelihood that at least some members of a species will survive under changed environmental conditions.
e.* *Students know* the conditions for Hardy-Weinberg equilibrium in a population and why these conditions are not likely to appear in nature.
f.* *Students know* how to solve the Hardy-Weinberg equation to predict the frequency of genotypes in a population, given the frequency of phenotypes.

8. Evolution is the result of genetic changes that occur in constantly changing environments. As a basis for understanding this concept:

a. *Students know* how natural selection determines the differential survival of groups of organisms.
b. *Students know* a great diversity of species increases the chance that at least some organisms survive major changes in the environment.
c. *Students know* the effects of genetic drift on the diversity of organisms in a population.
d. *Students know* reproductive or geographic isolation affects speciation.
e. *Students know* how to analyze fossil evidence with regard to biological diversity, episodic speciation, and mass extinction.
f.* *Students know* how to use comparative embryology, DNA or protein sequence comparisons, and other independent sources of data to create a branching diagram (cladogram) that shows probable evolutionary relationships.
g.* *Students know* how several independent molecular clocks, calibrated against each other and combined with evidence from the fossil record, can help to estimate how long ago various groups of organisms diverged evolutionarily from one another.

2. North Carolina

From the Executive Summary:[51]
Concerns: The following concerns were expressed repeatedly throughout the revision and review process:

- Teaching of biological, geologic, and technological evolutionary process as outlined in the National Science Education Standards. [52]...

Purpose

– Middle School Education
By the end of eighth grade, all students should have constructed understanding of the following concepts, theories, and universal laws:

- Cell theory.
- Human body systems.
- Heredity and genetics.
- Population dynamics.
- Diversity and adaptations of organisms.
- Change over time of life and landforms.
- Structure of the earth system.
- Earth in the universe. ...

– High School Education
By the end of twelfth grade, all students should have constructed an understanding of the following concepts, theories, and universal laws. ...

- The cell.
- Molecular basis of heredity.
- Biological evolution.
- Interdependence of organisms.
- Energy in the earth systems.
- Geochemical cycles.
- Origin and evolution of the earth system.

- Origin and evolution of the universe.

Description of Program Strands

Science is a way of knowing about the world. In science, explanations are limited to those that can be inferred from confirmable data - the results obtained through observations and experiments that can be substantiated by other scientists. (NAS Evolution, 1998) When observations of a phenomenon have been confirmed or can be repeated, they are regarded as fact. Any scientific confirmation is, however, tentative, because it is always possible that the results occurred by chance.

A scientific theory is a body of continually refined observation, inference, and testable hypotheses. Because science is never irrevocably committed to any theory, no matter how firmly it appears to be established, science is not dogma. Any theory is always subject to change in the light of new and confirmed observations. Students should be taught that uncertainty is not a weakness, but a strength that leads to self-correction.

These general statements are followed by grade-specific standards from which the following are excerpted. At each grade level, general principles are followed by specific items:

Grade 8

Constancy and Change

Learners will study the constancy and change of natural and technological systems. The strands provide a context for teaching content throughout all goals. In-depth studies include:

- Hydrosphere.
- Population Dynamics.
- Evolution Theory.
- Motion and Forces.

Competency Goal 3

The learner will build an understanding of evidence of change or constancy in organisms and landforms over time.

Objectives:

3.01 Interpret ways in which rocks, fossils, and ice cores record Earth's geologic history and the evolution of life.

3.02 Evaluate evolutionary theories and processes:

- Biological.
- Geological. ...

3.03 Examine evidence that the movement of continents has had significant global impact:

- Distribution of living things.
- Major geological events.

Biology, Grades 9-12

Nature of Scientific Knowledge

All scientific knowledge is tentative, although many ideas have stood the test of time and are reliable for our use.

Theories "explain" phenomena that we observe. They are never proved; rather, they represent the most logical explanation based on currently available evidence. Theories just become stronger as more supporting evidence is gathered. They provide a context for further research and give us a basis for prediction. For example, the theory of biological evolution is an explanation for phenomena such as diversity of species. Gene theory is an explanation for relationships we observe between one generation and the next. Laws are fundamentally different from theories. They are universal generalizations based on observations of the natural world, such as the nature of gravity, the relationship of forces and motion and the nature of planetary movement. Scientists, in their quest for the best explanations of natural phenomena, employ rigorous methods. Scientific explanations must adhere to the rules of evidence, make predictions, be logical, and be consistent with observations and conclusions. "Explanations of how the natural world changes based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not scientific." (1995, National Science Education Standards)

Competency Goal 2

The learner will develop an understanding of the continuity of life and the changes of

organisms over time.

Objectives

2.01 Analyze the molecular basis of heredity/DNA including:

- Replication.
- Protein synthesis (transcription, translation).

2.02 Compare and contrast the characteristics of asexual and sexual reproduction.

2.03 Interpret and use the laws of probability to predict patterns of inheritance. ...

2.06 Examine the development of the Theory of Biological Evolution including:

- The origins of life.
- Patterns.

Variation.
Natural selection.

Competency Goal 5

Students will develop an understanding of the behavior of organisms, resulting from a combination of heredity and environment.

Objectives:

5.01 Evaluate the survival of organisms and suitable adaptive responses to environmental pressures.

5.05 Evaluate and explain the evolution of behavioral adaptations and survival of populations.

Earth/Environmental Science Grades 9-12

Historical Perspectives - Both great advances and gradual knowledge building in science and technology have profound effects on society. Students should appreciate the scientific thought and effort of the individuals who contributed to these advances. Some examples are Eratosthenes' determination of the size of the earth, Wegener's apparent "fit" of the continents, Kepler's laws of planetary motion, and James Hutton's simple yet powerful idea that the earth history must be explained by what we see happening now. Today, Hutton's uniformity of process principle is used to interpret the structure of landing sites on Mars.

Competency Goal 3

The learner will build an understanding of the origin and evolution of the earth system.

Objectives:

3.01 Interpret the order and impact of events in the geologic past:

- Origin of the earth system.
- Origin of life.
- Relative and absolute dating techniques.
- Statistical models of radioactive decay.
- Diversity of life through time.
- Fossils evidence of past life.
- Evolution/extinction of species.

3.02 Assess evidence for and the influence on the divisions of geologic time of the major geologic events and paleoclimatic changes in global geologic history:

- Uniformitarianism.
- Unconformities.
- Stratigraphic principles.
- Floral and faunal succession.

Competency Goal 6

The learner will acquire an understanding of the earth in the solar system and its position in the universe.

Objectives:

6.01 Analyze the formation of the solar system. ...

6.04 Assess the current scientific theories of the origin of the universe.

6.05 Examine the sources of stellar energies.

Assess the spectra generated by stars and our sun as indicators of motion:

- Doppler effect.
- Red and blue shifts. ...

6.07 Evaluate Hubble's Law and the concept of an ever-expanding universe.

6.08 Evaluate the life cycle of stars in the Hertzsprung-Russell Diagram (H-R Diagram).

Appendix B: Evolution and Its Discontents

This Appendix expands the discussion in the section entitled "Extrascientific Issues," but is still necessarily too brief to be more than an introduction to that complex topic. For sources of more complete discussions, see the Bibliography.

Among the many species of anti-evolutionists, we have mentioned in passing the Black Muslims, who ascribe an unsupportably large age to the universe, and a number of Native American groups, whose arguments begin and end with the assertion that their ancestors have lived in the same place for an infinite time. We have also touched on the views of Marxists and others who object to any view that attributes a considerable degree of human behavior to the human genetic makeup. One might expand at length on a rich biota of anti-evolutionists, but as we have already noted, most have had little influence on public-school instruction. However, the class of anti-evolutionists generally called creationists deserve more attention in the context of a study of science education in U.S. public schools. As we have noted, creationism has evolved over the past century or so. Though finer distinctions may be made, for our purposes creationists belong to two genera, one of which comprises three species.

The Biblical Literalists

The genus of biblical literalists asserts that all scientific conclusions must bear the test of concord with the Bible, especially the first nine chapters of Genesis and the time scale that can be inferred from the genealogies of the Old Testament. One species, the day-agers, achieves this concord by agreeing that the six days of creation in Genesis 1 were not twenty-four hour days but were of any length that the geological, biological, and astronomical records require. A second species, the gap theorists, asserts that an epoch of great length elapsed between the events described in Genesis 1 and those in Genesis 2, and that most or all of the generally accepted history of the earth transpired in that epoch. These two species dominated the Protestant creationist discourse from about 1900 until about 1960. Subsequently, however, the third creationist species — the young-earthers — which had earlier been confined mostly to Seventh-Day Adventist circles, broadened and came to dominate Protestant evangelical creationism. This group of literalists insists on compressing the entire history of the universe into six twenty-four-hour days.[53] Their tactics in opposing standard evolutionary biology is two-branched.

First, young-earthers try to poke holes in any aspect of evolutionary theory, arguing that any inconsistency or error will result in the collapse of all aspects of evolutionary biology (and geology and cosmology as well) and will as a necessary and inevitable consequence validate their own account of the history of the universe.[54] Second, they attempt to deal with the weaknesses in their own constructs under the rubric of "creation science," a concept whose development was driven at least in part by judicial decisions that interdicted the teaching of older forms of creationism in public-school science classes on grounds that they constituted religion and not science.

Both tactical branches are clearly unsupportable. Evolutionary theory is extraordinarily robust, being based on an enormous amount and variety of evidence. Indeed, errors are invariably discovered not by creationists but by mainstream biologists, and are corrected. A favorite example of young-earthers is Piltdown Man, a compound of modern human and anthropoid skull fragments which puzzled paleoanthropologists for several decades before it was definitively identified as a fraud. But the discovery of the fraud was made not by creationists but by anthropologists who had never been able to reconcile the implications of the skull with the much broader range of other evidence.

Another common young-earth assertion is that there are no transitional forms in fossil sequences. In one sense, this is incorrect; there are many sequences in which the evolution from form to form is very clear. The evolution of the horse is a well-known example. In another sense, finding a fossil intermediate between two fossils already known simply creates two "gaps" where one existed before. Such an objection cannot, of

course, be taken seriously; see the endnotes that accompany the Alabama disclaimer (on p. 23).

But even if somehow the entire structure of evolutionary biology were overthrown, it would be no argument in favor of the Genesis account, which would have to take its place with all the other, mutually inconsistent, creation stories — plus an indefinitely large group of other proposals that might be put forth.

Young-earthers must also bear the burden of consistently explaining a vast range of scientific evidence. For example, they must account for the Grand Canyon as a runoff channel of Noah's flood, an event that is supposed to have taken about one year. Attempts to do so have not even come close to accounting for the evidence. To give another example, young-earthers must account for the arrival of light at Earth telescopes from sources billions of light-years away during the few thousand years they allow since the Creation. The "explanation" asserts that the speed of light has decreased markedly over time, so that a distance of billions of light-years could previously be traversed in much less time than billions of years. Of the many objections to this assertion, the Planck formula $E = hc/\lambda$ requires that light of a given wavelength λ (say, visible light) must consist of quanta whose energies E increase proportional to any increase in the value of c, the speed of light. The inference, then, is that Adam and Eve would have fried instantly under the bombardment of visible-light photons that in their day had the clout of present-day gamma rays. This is a typical example of how the tight interconnectedness of scientific theory prevents one from distorting one item without forcing distortion of a host of others, too.

The Intelligent-Design Proponents

The other genus of creationists comprises the intelligent-design proponents. They tend to reject, de-emphasize, or obfuscate young-earth arguments of the sort noted above. But they share with the young-earthers the deep concern that adherence to an evolutionary point of view is tantamount to atheism and hence (from their point of view) immorality. This is quite at variance with the facts, as countless evolutionary scientists in all fields are deeply religious, including some who adhere to Protestant evangelical faiths. The Bibliography lists several books by such persons.

Nevertheless, let us consider two of the main arguments of the intelligent-design genus, one "scientific," the other theological.

The "scientific" argument is a modification of one made by Paley[55] two centuries ago and used by other creationists since. Consider the human eye. It has a number of components — retina, lens, iris, cornea, and so on — which work together in a highly integrated fashion to produce an image interpretable by the brain. If any component is absent, the eye does not function. Paley, writing a half century before Darwin, argued that an eye, like a watch, cannot have arisen by chance. How then, argue Paley's modern followers, can a random evolutionary, step-by-step process account for the eye?

The answer has two parts. First, evolution is not a random process. Though genetic variations are random, natural selection works effectively to single out those that are advantageous. Second, an eye need not be as sophisticated as a human eye to be useful to its owner. The skins of most animals are sensitive to infrared (heat) radiation. Now consider an animal whose skin has one or more light-sensitive spots — a very modest shift in wavelength response. The animal cannot see images, but can distinguish light from dark and might well detect the shadow of a predator and escape. One of its descendants might possess a similar light-sensitive spot located in a pit, which would serve to concentrate the light and increase sensitivity. If the pit happened to contain water functioning as a lens, it might do even better. Subcutaneous nerves might evolve to serve the spot better, and more sensitive pigments as well. And so on.

Now, this may seem speculative, but the fact is that eyes of one sort or another have evolved independently in many phyla, and there is abundant evidence as to how this has happened. Some eyes, like the insect eye, are quite different from ours. Others, like the eye of the octopus, resemble ours superficially — a consequence of a phenomenon called convergent evolution.

Could the vertebrate eye have been designed by an Intelligent Designer? If so, the designer might have been a flunk-out from engineering

school. Why, for instance, would a designer locate the efferent nerves that serve the retina in front of the light-sensitive cells, where they obscure some of the incoming light? Well, perhaps the mammal was a first try; the designer got it right in the octopus eye, where the nerves lie logically behind the light-sensitive cells.[56] And how does one account for all the vast variety over time and species, or for the observed convergences?

The most popular modern variation on this theme concerns the human blood-clotting mechanism,[57] perhaps because the arguments based on the eye have been so thoroughly refuted. The clotting of blood involves a long and very complex chain of chemical reactions. If any one of them fails, the blood does not clot well, or at all. But the evolutionary explanation is completely parallel to the simpler one that underlies the scientific understanding of the evolution of the eye.[58]

The other–more theological–intelligent-design objection to evolution is that it is "naturalistic." This is probably the objection closest to the heart of Philip Johnson, the best-known intelligent-design proponent. "Naturalistic" is construed to mean that scientists admit the existence only of the natural universe, whose components interact through a complex of cause-and-effect processes. Supernatural explanations are not admitted. Thus scientists — biologists in particular — must be atheists, since the Intelligent Designer (who may be identified with God by some if not all intelligent-design advocates) is denied existence.

This argument confuses and conflates two quite different senses of the term "naturalism," in rather the same way that young-earthers like to confuse different meanings of the word "theory." The naturalism to which Johnson objects has been more precisely defined by Robert Pennock as *ontological naturalism.* But ontological naturalism, a blanket denial of the existence of anything external to the natural universe, is not at all a prerequisite of evolutionary discourse or, for that matter, any other scientific discourse. What is important to scientific discourse is *methodological naturalism.* But this term is merely descriptive of the fact that science is limited to inquiry into natural causes of natural phenomena. It is simply not possible to solve a scientific question if one is willing to invoke a supernatural answer,[59] because supernatural answers foreclose further scientific inquiry. As we have already noted, a person who accounts for the motion of the planets by asserting that angels propel them is simply not going to be able to account for Kepler's laws of planetary motion in any kind of fruitful way. Newton was very religious but that did not stand in the way of his doing just that on the basis of gravitational forces rather than angels. Similarly, if one argues that an Intelligent Designer set out the human eye, or the blood-clotting mechanism, as an *ad hoc* product, one will never gain any insight into the natural processes involved. But this obligatory methodological naturalism by no means denies the existence of the supernatural, or of God, nor does it preclude scientists from being religious or leading moral lives.[60] It is a bit presumptuous, after all, to deny God the right to have designed the universe so that it operates according to the laws to whose elucidation scientists devote their efforts. This point, in a slightly different form, was made as early as 1615 by Galileo.[61]

Intelligent design treads on thin theological ice in another way as well: it is arrogant. Science deals with complexities, but to say that a system is *irreducibly* complex is tantamount to saying, "If I can't understand it, only divine intervention can account for it." Unfortunately for this point of view, the progress of science reduces the intelligent-designer's God to a god of the gaps — a god whose province is the ever-shrinking domain of human ignorance. Most persons, religious or not, find this conception of God a narrow and disrespectful one.

Science, Teleology, and Eschatology: Intelligent Design and Marxism

Creationists of most species are troubled by the exclusion of teleological and eschatological principles from the sciences. Evolution proceeds as it does, governed by a combination of chance and necessity. The necessity lies in the conformity of the process to all natural laws — those of physics, chemistry, and biology. The chance lies in the myriad contingencies, in which a star forms in a more or less dense cloud of matter, or a planet develops an asthenosphere on which continental and oceanic plates can float, or an individual

living thing finds itself in a congenial or hostile environment. One may readily sympathize with the persons who find this world-view uncomfortable, but neither they nor we can alter the natural world to suit our hearts' desires.[62]

It is interesting to note that the intelligent-design creationists and the Marxian anti-evolutionists share some fundamental perspectives. Both are committed to an eschatological world-view. For the creationist, the end of man is to seek perfection through the operation of agents to whose description scriptures are devoted — perfection which may well be achieved not in this world but another. For the Marxist, the last things will come to pass here on earth, where the utopian endpoint of pure communism will succeed capitalism and socialism through the operation of inexorable laws of history, as set down in a quite different set of scriptures.

Truth In Law, Truth In Science

There is also the matter of conceptions of Truth, which has different (though not incompatible) meanings in the contexts of science and of everyday human activities as these are distilled in normal legal proceedings. The difference, well understood in the scientific community, was set forth forcefully by Nobel laureate Kary Mullis, as follows.[63] For the scientist, truth is never final. It is always tentative, always based on a finite amount of available information, and always amendable in the light of new information, of which there is no predeterminable limit.

In the world of the law, a trial is preceded by a set of discovery proceedings whose purpose is to set forth the available evidence and make it available to all parties. Once these proceedings have ended, new evidence can be admitted only in unusual circumstances. The trial thus proceeds on the basis of a well-defined and clearly limited body of evidence. On the basis of this finite body of evidence, the trial proceeds to a verdict — a truth-telling — that is final and is modified or reversed only in a small proportion of cases.

Thus science never reaches a final determination of truth but is always open to new evidence (which, of course, must be critically evaluated). Legal proceedings use a closed body of evidence to reach a final determination of truth. Both of these methods are valid, of course. But they must not be confused. It is not surprising, perhaps, that creationist works have such titles as *Darwin On Trial,* or *Evidence That Demands a Verdict.*[64]

The Fecundity of Science and the Sterility of Creationism

A final difficulty inheres in all schools of creationism: They are sterile. In spite of numerous claims to scientific respectability, creationists have made no contribution to the progress of biology or any other of the historical sciences, in an era when those sciences are making progress at an unprecedented rate.[65]

Appendix C: State Documents Examined

This study is based on the science standards that were available as of August 2000. For the most part, they are the same documents used in Standards 2000. There were four significant updates: the District of Columbia, Idaho, Pennsylvania, and South Carolina. Nine other states have revised or reissued their standards but, at least with regard to evolution, the documents do not significantly differ.

The simplest way to access current state science standards is on the Internet. The Indiana Department of Education maintains a web page that gives current URLs for all state department of education, whence the individual state standards can readily be accessed: <http://doe.state.in.us/htmls/states.html>. The standards posted on individual state department of education web-sites are usually, though not always, up to date. Most states also make paper copies available; there is a charge for some.

Alabama

Alabama Course of Study: Scientific Literacy. Alabama State Department of Education, Bulletin 1995, No. 4

Alaska

Alaska Content Standards, undated

Arizona

Arizona Academic Standards: Science, August 1998

Arkansas

Science Curriculum Framework, Revised 1999

California

Science Content Standards, Grades K-12, Prepublication Version, 1998

Colorado

Model Content Standards, June 1995

Connecticut

Science Curriculum Framework, March 1998

Delaware

(1) Science Performance Indicators for Grades K-5 (February 1998), 6-8 (May 1998)
(2) Science Curriculum Framework: Content Standards for Grades 9-11

District of Columbia

Standards for Teaching and Learning, June 2000

Florida

Florida Curriculum Framework—Science, 1998

Georgia

Georgia's Quality Core Curriculum: Science, December 1997

Hawaii

Science Content Standards, August 1999

Idaho

Idaho Achievement Standards Draft I, June 16, 2000

Illinois

Illinois Learning Standards, July 1997

Indiana

(1) Science Proficiency Guide
(2) Indiana High School Competencies

Iowa

Iowa does not intend to write state standards.

Kansas

Curricular Standards for Science Education, December 1999

Kentucky

(1) Core Content for Science Assessment, Version 3.0, August 9, 1999
(2) Program of Studies for Kentucky Schools, Grades Primary-12, 1998
(3) Kentucky's Learning Goals and Academic Expectations, 1994
(4) Transformations: Kentucky's Curriculum Framework: Science, 1993

Louisiana

(1) Louisiana Science Framework, May 22, 1997
(2) LEAP for the 21st Century: Teachers' Guide to Statewide Assessment, Grades 4,8,11: Science, Preliminary Draft, October 1998

Maine

Maine Science and Technology Standards, 1997

Maryland

Science Content Standards, July 1999

Massachusetts

Science & Technology/Engineering Framework, revised draft August 1999

Michigan

Content Standards and Draft Benchmarks

Minnesota

K-12 Science Framework, September 1997

Mississippi

Science Framework, 1996

Missouri

(1) Framework for Curriculum Development in Science, K-12, 1996
(2) Assessment Annotations for the Curriculum Frameworks: Science, Grades 3, 7, and 10, undated

Montana

Standards for Science, June 1999

Nebraska

Nebraska L.E.A.R.N.S., May 1998

Nevada

(1) Nevada Science Content Standards for Grades 2, 3, 5, 8, and 12, August 20, 1998
(2) Indicators of Progress for Kindergarten and Grades 1, 4, 6, and 7, August 20, 1998

New Hampshire

(1) K-12 Science Curriculum Framework, 1995
(2) K-6 Science Addendum for the K-12 Science Curriculum Framework, August 1995
(3) 7-10 Science Addendum for the K-12 Science Curriculum Framework, August 1996

New Jersey

(1) Core Curriculum Content Standards for Science, 1996
(2) Directory of Test Specifications and Sample Items for the Grade Eight Proficiency Assessment (GEPA) in Science
(3) High School Proficiency Assessment (HSPA) in Science

New Mexico

Content Standards with Benchmarks, Fall 1996

New York

Mathematics, Science & Technology Guide

North Carolina

Science: Standard Course of Study and Grade Level Competencies, K-12, Final Draft, 1999

North Dakota

Science Standards, Spring 2000

Ohio

Model Competency-Based Science Program, 1996

Oklahoma

Priority Academic Student Skills: Science, May 2000

Oregon

Teaching & Learning Standards: Science, September 1999

Pennsylvania

Proposed Academic Standards for Science and Technology, March 15, 2000.
(*On July 12, 2000, the Pennsylvania Board of Education announced its intention to adopt these standards.*)

Rhode Island

Science Literacy for ALL Students: The Rhode Island Science Framework, Revised Edition, 1995

South Carolina

Science Curriculum Standards, January 2000

South Dakota

(1) Science Content Standards, June 1999

(2) *Technical Guide for Implementing Content* Standards: Science, Draft III, March 1999

Tennessee

Science Curriculum Grades K-12, September 1999

Texas

Texas Essential Knowledge and Skills for Science, August 1998

Utah

Elementary Science Core; Secondary Science Core, 1994

Vermont

Framework of Standards and Learning Opportunities: Science, Mathematics and Technology Standards, 1996

Virginia

Science Standards of Learning, June 1995

Washington

Essential Academic Learning Requirements Technical Manual, 1997

West Virginia

Documents (no title, no date) downloaded from http://access.k12.wv.us/~dschafer

Wisconsin

Model Academic Standards, 1998

Wyoming

Wyoming Science Content and Performance Standards, June 1999

Appendix D: Ratings of State Science Standards as a Whole

The criteria listed in this appendix were used to produce the overall grades for states' science standards, as set forth in *The State of State Standards 2000.* Those appraisals took place in 1999. These are *not* the criteria for the present evaluation of how well evolution is handled in state science standards. Note, too, that some states updated their standards after the 1999 appraisal, meaning that a different document was evaluated for the state's treatment of evolution.

The science standards appraisal conducted for *The State of State Standards 2000* employed twenty-five criteria organized into five categories. To read a more detailed explanation of the criteria and other supporting materials, see Lawrence S. Lerner, *State Science Standards: An Appraisal of Science Standards in 36 States, March 1998*, online at www.edexcellence.net.

Detailed grades for states' science standards are shown in Table D1 on page 43.

While numbers can never yield a complete assessment of academic standards, the degree to which a standard measures up to each criterion is roughly evaluated by means of a four-point scale:

0: The criterion is addressed not at all or in an unsatisfactory manner
1: The criterion is met spottily or inconsistently
2: The criterion is often or usually met
3: The criterion is met almost always or always, and in a perceptive and thoughtful manner

Because numbers cannot reflect some of the subtler aspects of a complex document, we adopted the following system: To each standards document we assigned an initial letter grade based entirely on the total numerical score. We then considered additional factors that might change the letter grade, and altered the grade by a maximum of one letter up or down in light of these factors. This alteration affected only three states.

The Criteria

A. Purposes, Expectations, and Audience

1. The standards document expects students to become scientifically literate, at depths appropriate to their grade levels.
2. The document can serve as the basis for clear and reliable statewide assessments of student learning and skills acquisition, both theoretical and practical.
3. The document is clear, complete, and comprehensible to all interested audiences: educators, subject experts, policymakers, and the general public.
4. The document expects student written work to be presented clearly in Standard English and, where called for, in acceptable mathematical language. It expects student oral presentations to be clear, well organized, logical, and to the point.

B. Organization

1. The standards are presented grade-by-grade or in clusters of no more than three to four grade levels.
2. They are grouped in categories reflecting the fundamental theoretical structures underlying the various sciences.
3. They pay proper attention to the elementary skills of simple observation and data gathering, the interpretation of systematic observations, and the design of experiments on the basis of a theoretical framework.

C. Coverage and Content

1. The standards address the experimental and observational basis of the sciences, and provide for substantial laboratory and/or field experience in the sciences. Replication of important classical experiments is encouraged. The primacy of evidence over preconception is made clear.
2. The standards stress the importance of clear, unambiguous terminology and rigor-

ous definition. Such terms as energy, mass, valence, pH, genotype, natural selection, cell, metabolism, continental drift, magnetic reversal, and cosmic background radiation are defined as rigorously as possible at the grade level concerned.

3. The standards address such issues as data analysis, experimental error, reliability of data, and the procedures used to optimize the quality of raw information. The stringent criteria for acceptance of data are made clear.
4. The standards expect students to master the techniques of presentation and interpretation of tabular and graphical data at increasingly sophisticated levels.
5. The standards address the need for systematic, critical interpretation of experimental/observational data within the framework of accepted theory. The continual interplay between data and theory, and the rejection or remeasurement of data and modification of theory where necessary, are stressed at all grade levels, commensurate with the students' degrees of maturity. The nature and role of scientific revolutions, and how or when they occur (or do not occur), are part of the curriculum for students sufficiently advanced to appreciate the issues involved.
6. The basic underlying principles of all the sciences are stressed. Examples include Newton's laws, conservation laws, and the microscopic/macroscopic connection in physics; the evolution of the universe and the structure of its parts (including the solar system) in astronomy; plate tectonics in geology; the roles of mass and energy conservation and the nature of the chemical bond in chemistry; and evolution and the molecular basis of life in biology. At the elementary levels, these principles may be exemplified by such observations as buoyancy, plant tropisms, and the gross structure of cells.
7. The increasing ability of students to grasp abstractions and generalizations is taken into account. The broad, less structured knowledge base laid in the early grades is consistently and methodically built up on the basis of progressively more sophisticated theoretical treatment as the students mature.
8. The standards emphasize the need to set forth the general methodologies of the sciences, but do not oversimplify this need into an artificial package called "the scientific method." The underlying commonalities of the sciences, as well as the distinctions among them, are made clear.
9. The standards consider the two-way relationships between science and technology, and between science and broader worldviews, and the way that science has helped to shape society. The standards stress the fact that science is intellectually satisfying as well as socially useful. A common interest in science can act as a strong unifying force among people who differ widely in other ways.

D. Quality

1. The standards are unambiguous and appropriate; that is, their meaning is straightforward and to the point.
2. They are specific but flexible; that is, they are neither so broad as to be vague nor so narrow as to be trivial.
3. They comprehensively cover basic knowledge, the importance of which is generally agreed upon by the scientific community; they are not, however, encyclopedic.
4. Standards are demanding:
   a. They expect increasing intellectual sophistication and higher levels of abstraction, as well as the skills required to deal with increasingly complex arrays of information, at successively higher educational levels. In light of the tight logical structure of the sciences, it is especially important that the standards also expect the knowledge gained by students to be cumulative, each level building on what has been mastered earlier.
   b. Their overall contents are sufficiently specific and comprehensive to underlie a common core of understanding of science for all students in all the schools of the state. They are suffi-

ciently demanding to ensure that this common core comprises understanding of the basic principles of all the sciences, and of their methodologies.

E. Negatives

1. The standards must not accept as scientific, or encourage, pseudoscientific or scientifically discredited constructs such as quack medical doctrines (*e.g.*, homeopathy, foot reflexology), vaguely defined "energy fields" or "auras," creationism and other nonscientific cosmologies, UFO visits, astrology, or mysterious "life forces."
2. The standards must not imply that scientific principles are race-, ethnic-, or gender-specific, or distort the history of science to promote racial-, ethnic-, or gender-based positions.
3. The standards must not confuse science with technology.
4. The standards must not encourage an anti-scientific or anti-technological worldview.

Table D1: Detailed Grades for Science Standards as a Whole

State	A. Purposes, Expectations & Audience	B. Organization	C. Coverage & Content	D. Quality	E. Negatives	Additional factors	Raw Score	Percentage	Grade*
Alabama	8	6	18	10	9	-	51	68%	D
Alaska	-	-	-	-	-	-	-	-	-
Arizona	12	9	24	14	12	-	71	95%	A
Arkansas	6	6	17	8	9	-	46	61%	F
California	12	9	27	15	12	-	75	100%	A
Colorado	8	9	18	12	12	-	59	79%	D
Connecticut	11	9	23	15	12	-	70	93%	B
Delaware	11	9	27	15	12	-	74	99%	A
District of Columbia	-	-	-	-	-	-	-	-	-
Florida	2	5	14	6	10	-	37	49%	F
Georgia	3	6	13	9	9	-	40	53%	F
Hawaii	6	8	18	11	12	-	55	73%	D
Idaho	-	-	-	-	-	-	-	-	-
Illinois	10	9	22	15	12	-	68	91%	B
Indiana	12	9	26	15	12	-	74	99%	A
Iowa	-	-	-	-	-	-	-	-	-
Kansas	0	3	2	1	1	-	7	9%	F
Kentucky	10	6	18	14	10	-	58	77%	D
Louisiana	11	8	19	14	12	-	64	85%	C
Maine	8	9	16	11	12	-	56	75%	D
Maryland	8	9	20	7	12	-	56	75%	D
Massachusetts	12	9	24	15	12	-	72	96%	A
Michigan	5	7	16	11	12	-	51	68%	D
Minnesota	11	9	24	15	12	-	71	95%	A
Mississippi	5	4	7	5	8	-	29	39%	F
Missouri	9	8	21	14	12	-	64	85%	C
Montana	6	9	17	7	10	-	49	65%	D
Nebraska	11	8	26	14	11	-	70	93%	B
Nevada	9	7	23	14	12	-	65	87%	C
New Hampshire	7	5	13	6	12	-	43	57%	F
New Jersey	12	9	23	15	12	-	71	95%	A
New Mexico	4	5	6	4	12	-	31	41%	F
New York	8	6	16	9	12	9	60	80%	C
North Carolina	11	9	26	15	12	-	73	97%	A
North Dakota	5	5	13	7	11	-	41	55%	F
Ohio	10	8	25	13	12	-	68	91%	B
Oklahoma	4	4	9	7	5	-	29	39%	F
Oregon	12	8	22	15	12	-	69	92%	B
Pennsylvania	-	-	-	-	-	-	-	-	-
Rhode Island	12	9	23	15	12	-	71	95%	A
South Carolina	11	7	26	14	12	-	70	93%	B
South Dakota	10	8	23	15	12	-	68	91%	B
Tennessee	7	6	14	6	10	-	43	57%	F
Texas	10	9	20	15	12	-	66	88%	C
Utah	11	9	22	15	12	-	69	92%	B
Vermont	10	9	24	14	12	-	69	92%	B
Virginia	5	6	9	12	12	5	49	65%	D
Washington	11	8	22	15	12	-	68	91%	B
West Virginia	4	4	12	6	10	-	36	48%	F
Wisconsin	8	7	16	9	12	8	60	80%	C
Wyoming	3	5	10	1	12	-	31	41%	F

*Percentages are converted to letter grades using this scale: A: 95-100%; B: 90-94%; C: 80-89%; D: 65-79%; F: 0-65%.

This table is an exact reproduction of Table E1 in Appendix E of *The State of State Standards 2000*. The information in the table was accurate when that report was published, but it may no longer be accurate because some states have revised their science standards since then.

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Annotated Bibliography

Dawkins, Richard, *The Blind Watchmaker,* Penguin, New York, 1986 and Norton, New York, 1987. Perhaps the most readable exposition of modern evolution theory, it addresses with beautiful clarity the main objections to evolution made by the intelligent-design proponents.

Eve, Raymond A. and Francis B. Harrold, *The Creationist Movement in Modern America,* Twayne Publishing, Boston, 1991. A sociologist and an anthropologist analyze the motives of creationists, mainly in terms of their moralistic imperatives and cultural anxieties.

Gilkey, Langdon B., *Evolution On Trial: Evolution and God At Little Rock, 1982,* Winston, Minneapolis, MN, 1985, University Press of Virginia, 1998. A distinguished theologian describes the issues in *McLean v. Arkansas* from a theological point of view. (See Overton, *infra.*)

Gross, Paul R., *Politicizing Science Education,* The Thomas B. Fordham Foundation, Washington, D.C., 2000. Evolution is but one of the scientific topics that have become subject to attack for political or ideological reasons. Various groups have exerted heavy pressure to have aspects of science — or science as a whole — revamped to suit their own desires. Though the oldest and best-known of such pressures is creationism, Gross cites such other areas as environmentalism, "feminist science," "other ways of knowing," and postmodern distortions of the meaning of scientific knowledge.

Haught, John, *God After Darwin: A Theology of Evolution,* Westview Press, Boulder, CO, 1999. A theologian discusses the theological ramifications of evolution by natural selection and how it can fit within a Christian framework.

Johnson, Philip, *Darwin On Trial,* Regnery, Washington, D.C. and InterVarsity Press, Downers Grove, IL, 1991. The best known of the modern "intelligent design" works, this book is couched in terms that clearly reflect Johnson's legal background. Johnson's later books in this area are more concerned with general issues of morality and religion.

Marty, Martin E. and R. Scott Appleby, eds., *Fundamentalisms and Society: Reclaiming the Sciences, the Family, and Education,* vol. 2 of *The Fundamentalism Project,* Univ. of Chicago Press, Chicago, IL, 1993. Of particular relevance are Chapter 2, "Religious Fundamentalism and the Sciences," by Everett Mendelsohn (pp. 23-41), Chapter 3, "The Creationist Cosmos of Protestant Fundamentalism," by James Moore (pp. 42-72), and Chapter 16, "Christian Fundamentalism and Education in the United States," by Susan Rose (pp. 452-489).

Miller, Kenneth, *Finding Darwin's God: A Scientist's Search for Common Ground Between God and Evolution,* Cliff Street Books, New York, 1999. A religious scientist evaluates traditional young-earth creationism and intelligent-design creationism and finds them scientifically wanting. He cogently explains how he can be an evolutionist and a practicing Christian.

Morris, Henry M. and John C. Whitcomb, Jr., *The Genesis Flood: The Biblical Record and Its Scientific Implications,* Presbyterian and Reformed Publishing Company, Philadelphia, PA, 1961 and later editions by other publishers. In this first "modern" creationist book, Morris, a hydraulic engineer, and Whitcomb, a theologian, modified, propagated, and made theologically acceptable for fundamentalists the views of George McReady Price (1870-1963) who had worked a half-century earlier but had received mixed acceptance of his views outside his own Seventh-Day Adventist circle.

National Academy of Sciences, *Science and Creationism: A View From the National Academy of Sciences,* National Academy Press, Washington, D.C., 1999. This booklet, intended for the general public, contains a fine brief exposition of the methods of the sciences and of the essentials of evolution as it pertains to all the sciences and especially its central role in the life sciences.

National Academy of Sciences, *Teaching About Evolution and the Nature Of Science*, National Academy Press, Washington, D.C., 1998. This booklet is intended mainly for teachers confronted with the problem of teaching evolution to students from creationist backgrounds without offense and without impinging on their religious convictions.

Numbers, Ronald L, *The Creationists: The Evolution of Scientific Creationism*, Alfred A Knopf, New York, 1992. This magisterial work by a leading historian of science was awarded the Albert C. Outler Prize in Ecumenical Church History. Focusing mainly on young-earth creationism, it traces the intellectual and political history of creationism in America and to some extent elsewhere from the mid-19th century on.

Overton, The Hon. W. R., *United States District Court Opinion, McLean v. Arkansas*, 1982, in Ruse, Michael, *But Is It Science? The Philosophical Question*, Prometheus Books, Buffalo, NY, 1988. This remarkably readable judicial opinion sets forth the reasons, later adopted by the U. S. Supreme Court in *Edwards v. Aguillard* (1987), that creationism is not science and cannot be taught as such in public schools.

Pennock, Robert T., *Tower of Babel: The Evidence Against the New Creationism*, MIT Press, Cambridge, MA, 1999. A philosopher of science deconstructs the arguments of intelligent-design proponents with precision and clarity.

Strahler, Arthur, *Science and Earth History: The Evolution/Creation Controversy*, Prometheus Books, Buffalo, NY, 1987. An encyclopedic examination and refutation of essentially all the arguments set forth by creationists, together with a close analysis of the methods of science, pseudoscience, and religion.

Toumey, Christopher, *God's Own Scientists: Creationists In a Secular World*, Rutgers University Press, New Brunswick, NJ, 1994. A cultural anthropologist describes the appeal of "creation-science" to religious conservatives, "seeing creationism as a system of cultural meanings about both immorality and science that helps fundamentalist Christians make sense of the realities, anxieties, and uncertainties of life in the United States in the late 20th century. ... Creationism ... is the subcategory of fundamentalism that ties those feelings [of immorality] to the problem of evolution." Discusses the complex conflicts within the creationist movement.

Endnotes

References here to author and title only are given more completely in the Bibliography.

[1] For convenience, we include the District of Columbia in the term "state" throughout this essay.

[2] Paul Gross, *Politicizing Science Education*, (Washington, D.C.: Thomas B. Fordham Foundation, April 2000).

[3] Both of these studies were published by the Thomas B. Fordham Foundation, Washington, D.C.

[4] More information about the criteria and the method of applying them can be found in *State Science Standards: An Appraisal of Science Standards in 36 States.*

[5] The other countries in which more than trivial anti-evolution pressures exist are Canada and Australia. But even in those countries, the pressures have had little practical effect on the teaching of public-school science.

[6] "Concepts without factual content are empty; sense data without concepts are blind." Immanuel Kant, *Critique of Practical Reason*, 1788.

[7] Francis Bacon, *New Atlantis, A Work Unfinished*, London, 1635.

[8] Thomas S. Kuhn, *The Structure of Scientific Revolutions*, (Chicago, IL: Univ. of Chicago Press, 1996, 3rd ed.).

[9] This monumental edifice of theory and fact makes it as silly to call modern evolutionary theory "Darwinism" (as creationists love to do) as it would be to call contemporary physics "Newtonism."

[10] A creationist who read this work in manuscript objected to the above description of a good approach to teaching evolution on grounds that creationists have no objection to many of the bulleted items; e.g., that offspring are similar to but not exactly like their parents. This objection highlights a common misconception of the scope of evolution theory. Evolution does not consist merely of the set of particular items to which a creationist objects. Rather it is a broad and tightly integrated theory with deep and extensive roots throughout the sciences. It is precisely for this reason that biology and the other historical sciences cannot be taught properly without reference to evolution.

[11] Curiously, most holders of this interpretation are also strongly committed to the doctrine of original sin, according to which humans have a propensity for evil-doing that is unique in the animal kingdom, and believe that the ills that beset all living things — including death itself — are a direct consequence of that human transgression.

[12] Mary Beth Marklein writes "Consider Rep. Tom DeLay, R-Texas, who last summer ventured that tragedies like the Columbine High School shootings would continue as long as 'our school systems teach the children that they are nothing but glorified apes who are evolutionized [*sic*] out of some primordial soup of mud.'" *USA Today*, July 21, 2000.

[13] John Ray, *The Wisdom of God Manifested In the Works of the Creation*, London, 1691.

[14] William Paley, *Natural Theology: Evidences of the Existence and Attributes of the Deity, Collected From the Appearances of Nature*, London, 1802.

[15] Intelligent-design advocates often conflate two distinct senses of the word "naturalism," and thus obfuscate the real issues; see the discussion in Appendix B and, for more detail, Robert T. Pennock, *Tower of Babel* (Cambridge, MA.: MIT Press, 1999).

[16] Law professor Philip Johnson, a leading proponent of the intelligent-design movement, has ventured to link the evolutionary world-view with

abortion, homosexuality, pornography, divorce, genocide, and bestiality; see Pennock, *op. cit.*

[17] Because his grossly oversimplified Lamarckian adaptationism was consistent with the Marxist view of human society, the charlatan Trofim D. Lysenko gained access to Stalin's (and later Khrushchev's) ear, and dominated Soviet biology and agronomy for many years to the great detriment of both. Khrushchev's eventual fall was due in large measure to the catastrophic failure of Lysenko's schemes for agricultural development. See Zhores A. Medvedev, *The Rise And Fall Of T. D. Lysenko,* (New York: Columbia Univ. Press, 1969).

[18] The mid-19th-century Oneida Colony was but one of many social experiments based on such utopian views.

[19] Barbara Ehrenreich and Janet McIntosh, "The New Creationism: Biology Under Attack," *The Nation*, June 9, 1997, pp. 11-16 is a good summary of the major left-wing objections to evolution (and, indeed, to the ascription of any aspect of human behavior to biological causes.) Other forms of left-wing antiscience and pseudoscience are widely popular among intellectuals who know little or nothing about science. See, *e.g.*, Paul Gross and Norman Levitt, *Higher Superstition: The Academic Left and Its Quarrels With Science,* (Baltimore, MD.: Johns Hopkins Univ. Press, 1994), and Matt Cartmill, "Oppressed By Evolution," in *Discover* Magazine 19 (3), March 1998, pp. 78-83. Alan Sokal's hoax on the editors of the journal *Social Text* opened some of this sesquipedalian nonsense to public view. See Alan Sokal and Jean Bricmont, *Fashionable Nonsense,* (New York: Picador, 1998).

[20] For a discussion of the disfigurement of the first two subjects, see Gross, *Politicizing Science Education,* pp. 5-7 and note 14, and several articles in *The Textbook Letter,* one of which is cited in Gross's note 14. For mathematics, see Norman Levitt, *Prometheus Bedeviled,* (New Brunswick, NJ.: Rutgers University Press, 1999), chapter 3.

[21] Intelligent-design creationism does not share the "redneck" image that dogs young-earthism, and thus offers creationism-minded education officials a way of attacking scientific knowledge that invites less ridicule.

[22] Levitt, *op. cit.*, pp. 17-18.

[23] This poll was conducted by DYG, Inc. (the firm headed by Daniel Yankelovich) for People For the American Way. The complete publication may be found at <http://www.pfaw.org/issues/education/creationism-poll.pdf>.

[24] *Epperson v. Arkansas*, 393 U.S. 97 (1968) put an end to explicitly anti-evolution laws, the most famous of which was the one under which the Scopes "Monkey Trial" was held in 1925. *Edwards v. Aguillard*, 482 U.S. 578 (1987) recognized that creationism is not science but religion, and therefore invalidated "balanced treatment" laws that required the teaching of creationism (dubbed "creation-science" by its advocates) whenever evolution was taught in science classes.

[25] *Ibid.*

[26] Not surprisingly, most of these states did well in the overall evaluation of their science standards. See *The State of State Standards 2000,* (Washington, D.C.: Thomas B. Fordham Foundation, 2000), in which six of the ten ranked A, two B, one D, and one (PA) was not evaluated because its standards were not yet available.

[27] Lawrence S. Lerner, *State Science Standards: An Appraisal of Science Standards in 36 States,* (Washington, D.C.: Thomas B. Fordham Foundation, 1998).

[28] The color of my hair, for example, has changed over time from brown to white, but that does not constitute evolution. And the tanning of my skin when I sunbathe is biological adaptation but not evolution.

[29] At Grade 9, "The learner will ... investigate degrees of kinship among organisms and groups of organisms."

[30] This is a typical creationist misuse of the tech-

nical term *microevolution,* which denotes the process that leads to variation within a species. While the variation over time of the average color of the wings of the peppered moth is an example of microevolution, the radiation of the pioneer stock of Galápagos finches into thirteen distinct species comprising four genera is by definition an example of macroevolution. Most creationists admit the possibility of microevolution but deny that the process can proceed so as to result in diverse species, let alone still broader spectra of living things. In order to avoid overcrowding Noah's Ark, some creationists adhere to the Biblical term "kinds" rather than species as the limiting barrier to evolution. In creationist literature, however, the breadth of a kind can vary from a species to a phylum, including everything in between.

[31] <http://www.sunflower.com/~jkrebs/5th-Aug.html>.

[32] The creationist candidates were all Republicans.

[33] That evolution has taken place and accounts for the life that exists on earth today is not controversial among scientists, though there is vigorous controversy concerning individual details of the theory or the meaning of individual facts such as particular fossils or DNA sequences. To say that evolution is "presented by some scientists" is a deliberate distortion, since in fact "some" must be interpreted to mean "essentially all" — indeed, all those who actually contribute to the progress of the science.

[34] A very large part of science deals with things or events that have not been or cannot be observed directly with the unaided senses. No one was present when an extinct or long-dormant volcano such as Haleakala was formed, but we can confidently infer how it formed by observing similar live volcanoes such as Mauna Loa. We cannot see atoms or distant galaxies directly, but we have instruments that reveal them to us in great detail.

[35] This is an attempt to confuse the reader by conflating the scientific meanings of the words "theory" and "fact" with their everyday meanings. In a detective novel, the sleuth studies the scene of the crime and conceives a "theory" — that is, a guess or hypothesis — as to what happened and who is guilty. As he investigates further, the "theory" becomes a "fact" when he confronts the perpetrator with incontestible evidence. But in science, a theory is a logical construct, often very elaborate, which is used both to tie together a wide spectrum of superficially unrelated observations — "facts" — and to make predictions as to what other observations may be expected under given, as yet unobserved circumstances. In scientific terms, the word evolution refers both to a theory and to an enormous body of facts. As is the case with other well-established scientific theories such as the theory of planetary motion or the theory of chemical bonding, evolution has no tenable rivals. Note that this distortion of the terms "theory" and "fact" does not occur in the standards document itself. One may infer that the authors of that document are scientifically competent but operating under externally imposed restrictions, while the sticker is more directly a product of the Board of Education itself.

[36] See Notes 30, 34, and 35. Note also the absurdity of the assertion that "Evolution [refers] to the change of one living thing to another, such as reptiles into birds." Lizards do not metamorphose into hummingbirds, and only gross ignorance or gross prejudice could lead anyone to state that any scientist has ever held such nonsense.

[37] Science is not concerned with teleology. The use of the word "undirected" pretends that science is an antireligious way of thinking, which is offensive to both science and religion.

[38] This is a muddled confusion of scientific with religious thought. In theology, "belief" means a tenet taken *a priori* without proof, often on the basis of scripture, tradition, or authority. Theological argument begins with, rather than ends with, belief. In science, the term "belief" is generally avoided, as science proceeds not on the basis of belief but on the basis of observation and tentative, more or less confident, assumption. The term "proof" is, strictly speaking, reserved for mathematical proofs; scientists proceed on the

basis of successive, cumulative confirmation. In this sense, the Alabama statement is again offensive to both theological and scientific thought.

[39] Note that none of the following bulleted items has anything to do with the *origin* of life. Biological evolution, by definition, deals with the way in which living things have descended with modification from their earliest living ancestors.

[40] The use of the term "major groups" here and in the following two bullets is both vague and misleading. Most persons would consider amphibians, reptiles, birds, mammals, and flowering plants to be "major groups," but none of these occur in the Cambrian context. There, the term could refer at best only to invertebrate phyla (some now extinct) and very simple ancestors of vertebrates.

[41] The Cambrian explosion is based on two landmark events in the evolution of living things: the emergence of multicelled organisms and the subsequent emergence of hard body parts such as shells and invertebrate exoskeletons. These allowed exploitation of previously unattainable ecological niches, and also fossilized more readily than soft body parts. This objection has carried even less weight since the discovery, over the past decades, of a wide variety of Precambrian fossils, many of which are microscopic. It is curious that anti-evolutionists present the Cambrian explosion as a "problem for evolution," when in fact it is an active and exciting area of research and discovery.

[42] One might equally well ask, "Why have no new major language groups appeared since the major part of the earth's land area was settled, and why have some disappeared?" Most major invertebrate body plans appeared in the Cambrian; some have propagated, some have disappeared, and a few exist today but are rare. Just as it is unlikely that a major new non-Indo-European language group will appear in Europe today, it is unlikely that a major new body plan will evolve today.

[43] In fact, many transitional fossils are known in many evolutionary sequences, and more are discovered every year. In one trivial sense, however, this question is unanswerable: If one finds a transitional fossil to fill the gap between two already known, related fossils, one creates two (smaller) gaps where only one existed before.

[44] This is a major subject of study of a recently expanded area of evolutionary biology called evolution and development, or "evo-devo" for short. Quite a lot of the answer is known now — thanks to scientific investigations guided by evolutionary theory, much more than was known a few decades ago — and more comes to light every day. The sequencing of the human genome will doubtless greatly stimulate the further development of this area.

[45] The origin of life is the subject not of biological evolution but of the active infant field of prebiotic evolution. Absent the preceding material, the children of Alabama would have a far better chance of making such contributions!

[46] An abbreviated version of this sticker statement appears in the front material of the Alabama science standards document. Ironically, the statement conflicts with and contradicts the following statement, which occurs in the same document three paragraphs earlier:

> During adolescence the exposure to facts, generalizations, theories, principles, and laws is begun. As students mature, these early concepts expand into more complete understanding and complex applications.

[47] The birth of modern chemistry in the late 18th century presents an interesting illustration of a reaction to this lack of democracy. When Antoine Lavoisier laid the foundations for modern quantitative chemistry, the renowned encyclopedist Denis Diderot objected vehemently. The practice of Lavoisier's chemistry, he complained, was restricted to professionals with strong mathematical backgrounds and access to expensive equipment. Rather, he argued, chemistry ought to proceed along traditional lines that could be pursued by the honest country apothecary in his spare time. Needless to say, this well-meaning chemical democracy did not prevail because it could not produce comparable results, though dis-

taste for Lavoisier's aristocratic and elitist background doubtless contributed to his death by guillotine.

[48] For a detailed and eloquent explication of the tension between science and democracy, see Levitt, *Prometheus Bedeviled*, especially the Introduction.

[49] Andrew J. Petto, in *The Chronicle of Higher Education*, December 17, 1999.

[50] California State Board of Education, *Science Content Standards for California Public Schools: Kindergarten Through Grade 12*, 2000, <http://www.cde.ca.gov/cdepress/Sci_Std.pdf>. Also ISBN 0-8011-1496-9.

[51] North Carolina Standard Course of Study: Science K-12, 1998, Department of Public Instruction. Also <www.dpi.state.nc.us/curriculum/science/index.html> and linked sites.

[52] National Research Council, *National Science Education Standards*, (Washington, D.C.: National Academy Press, 1995).

[53] It is interesting to note that, contrary to the story line in the well-known play and motion picture *Inherit the Wind*, William Jennings Bryan was not a young-earther and did not insist on creation in six 24-hour days. His objections to evolution centered on an unwillingness to admit a relationship between humans and the rest of the animal kingdom.

[54] Creationists have repeatedly predicted the imminent collapse of evolutionary biology and the "conversion" of the profession to their views. For example, in 1990 the Institute For Creation Research, the most prominent young-earth think tank, repeatedly declared the 1990s to be the "Decade of Creationism." That did not come to pass. Intelligent-design proponents have set up web sites setting forth similar timetables for the triumph of their views; the "wedge project" gives itself 25 years from 1998; see <http://www.freethought-web.org/ctrl/archive/wedge_document.html>.

[55] See note 14.

[56] Evolution accounts quite naturally for such "kluges." Evolutionary processes begin with what is already present, not with a textbook-perfect design from scratch. Another example is the evolution of bipedality in humans. The hands become free to do the wonderful things that human hands can do, but the price paid is backaches, slipped disks, and hemorrhoids among other ills. Design from scratch might lead to a centaur-like creature with four legs for proper support and two arms. But humans necessarily evolved on the quadrupedal mammalian body plan that was already in place, and had to make do with that.

[57] The blood-clotting mechanism is the favorite example of Michael Behe who, as a biochemist, is the one of the few adherents of the intelligent-design movement with specific training in the life sciences. See his *Darwin's Black Box*, (New York: The Free Press, 1996).

[58] The "Rube Goldberg" nature of many (if not most) multi-enzyme systems arises from the same imperative of evolutionary history described in Note 56. The system that evolves to fill a necessary function arises from something already in place, perhaps having a different function. Neatness doesn't count.

[59] The official Roman Catholic position on biological evolution embodies this distinction in a clear way. The Catholic Church is completely comfortable with evolution as scientists have discovered and continue to discover its details and ramifications (employing naturalistic *methodologies*) with the proviso that at some point God instilled a soul in the first being who thus *ipso facto* became human in the theological sense — a proviso at variance with *ontological* naturalism only.

[60] This discussion is heavily abridged from Pennock, *Tower of Babel*.

[61] Galileo Galilei, *Letter To the Grand Duchess Christina*, subtitled *Concerning the Use of Biblical Quotations In Matters of Science*, in

Discoveries and Opinions of Galileo, Stillman Drake, ed., (New York: Anchor Books, 1957). Galileo argues that God speaks to mankind through two books — the Book of Scriptures and the Book of Nature. Since they have the same author, they cannot contradict one another. However, apparent contradictions arise through misinterpretations, which are at least as likely in the former case as in the latter.

[62] There is something transcendent in deferring to Nature, granting that she operates according to laws that are not ours and are not necessarily to our liking. For those who profess the existence of a deity, this deference to nature is nothing less than a deference to the word and wisdom of God. And indeed, scientists both religious and nonreligious often observe that their confirmed discoveries of the workings of nature are always more beautiful and ramified than the hypotheses, however clever, that they have discarded on the way.

[63] Mullis made this point in the course of a lecture at California State University, Long Beach in the spring of 1998. At the time, he had been asked to serve as an expert witness for the defense in the high profile O. J. Simpson trial, and had thought deeply about the task. (As matters developed, he did not testify.)

[64] Josh McDowell, *Evidence That Demands a Verdict,* (Nashville, TN: NelsonWord Publishing Group, 1993).

[65] See Eugenie C. Scott and Henry P. Cole, "The Elusive Basis of Creation 'Science'," *Quarterly Review of Biology,* March 1985, pp. 21-30.

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